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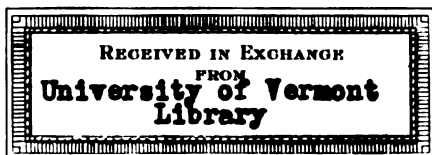
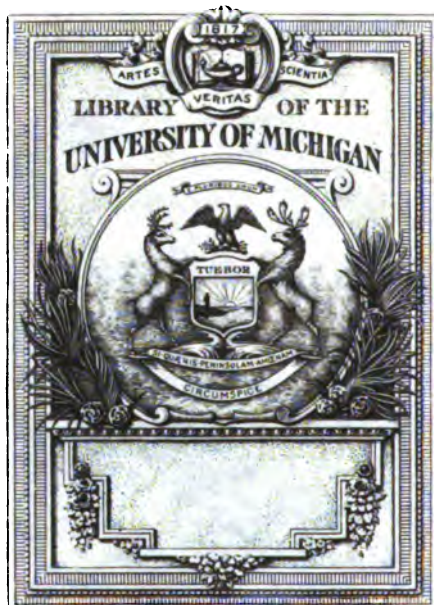
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EXPERIMENT STATION
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Potato Scab

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BULLETIN 184: POTATO SCAB

BY B. F. LUTMAN AND G. C. CUNNINGHAM

SUMMARY

1. The ordinary scab of the potato is due to an increase in growth in the cork layer. This stimulation of the cork is produced by the growth of an organism on its surface and in its outer cell layers. Chemical substances are formed which are absorbed and which cause the cork cells to increase both in size and number.

2. Under the scab lesions, the cells often contain fat-reacting bodies of various sizes, which in some cases assume the coccus shape.

3. The organism producing scab is the one described by Thaxter as *Oospora scabies* but which had been previously described and named as *Actinomyces chromogenus* by Gasperini.

4. *Actinomyces chromogenus* is a wide spread organism, which is found in practically all soils, so far as known, but is most numerous in those soils which are rich in humus.

5. Parasitism is facultative and may be induced by an alkaline condition of the soil in the presence of moisture and an abundance of organic matter. Some strains may have developed this character to a greater extent than others, but no morphological or cultural characters as yet found show such differences.

6. The organism is probably spread much more through manure and humus than through scabby potatoes. However, use of the latter as seed is to be avoided (or the tubers disinfected), for the reason that they introduce a heavy inoculation of strains already strongly parasitic at the point where the new tubers are to be formed.

7. The most hopeful method of attack on the organism in the soil is to change the neutrality or slight alkalinity of the latter to a weak acidity. The use of flowers of sulphur seems also to be helpful in diminishing the amount of scab, but its use is apt to prove harmful to other crops if applied in too large quantities.

8. No varieties of potatoes seem to be wholly resistant to the disease but there are some differences as between varieties in this property. The cause of these variations is not clear.

INTRODUCTION

The present publication is a study of the potato disease known in America as Deep Scab, Common Scab, *Oospora* Scab, or, sometimes, as American Scab. In France the same disease, although confused with other types, is called "Gale" and in Germany, "Schorf." There are also included brief descriptions of other potato diseases which are spoken of as special forms of scab caused by organisms other than that which Thaxter (74) discovered in its relation to scab and placed among the fungi as *Oospora scabies*, but which one of us (17) lately assigned to one of the groups of the higher bacteria. These diseases will be dealt with briefly and only in order to distinguish them from the common form of scab, known to all growers in America.

Such a lengthy discussion of the subject at this time can be excused on the ground that even after so much literature has appeared, expressing so many varied and contradictory theories regarding the nature, cause, prevention and treatment of scab, the disease is still abundant wherever potatoes are grown. Indeed, there is a strong suspicion among potato growers and those interested in the question that the prevalence of potato scab is increasing rather than decreasing. Certainly wherever potatoes are grown year after year in the same soil the disease becomes more abundant; and at the present writing there is no definite, well known method for the prevention or control of the disease once it has become established in the soil.

While we possess valuable information regarding the direct cause of the disease, and also as to methods for freeing the seed tuber of the scab germs by disinfection before planting the seed in the soil, we have no exact information regarding the indirect causes—conditions which may enable the organism to become more active or abundant and which possibly at the same time tend to make the potato tuber more susceptible to the attack of the scab organism. These may be brought

Note—The studies herein reported have been conducted by the writers at this Station during the last four years. The original suggestion of the problem, the isolation of the German cultures, and the study of the pathology of the tissues are to the credit of the senior author. The junior author has been in charge of practically the entire laboratory and field work. The authors assume joint responsibility for everything included.

Messrs. H. F. Johnson and F. S. Holden, College of Agriculture, University of Vermont, 1914, in connection with their senior thesis work, have also made contributions which have been of service, Mr. Johnson on the organisms of beet scab and Mr. Holden on the effect of scabbing on the germination of cuttings. Thanks are due to Dr. Otto Appel of the Biologische Anstalt at Dahlen and to Prof. Max Koernicke of the Botanical Institute of the Poppelsdorfer Agricultural College for allowing the senior author to work in their laboratories while isolating some of the organisms; to Dr. H. T. Gussow of the Dominion Experimental Farms, Ottawa, Canada, for samples of British potatoes and for photographs of powdery scab and of potato wart disease; and to Mr. W. A. Orton of the Bureau of Plant Industry of the United States Department of Agriculture for photographs of powdery scab.

about by numerous soil conditions, such as an alkaline reaction, a high state of fertility, abundance of organic compounds, the moisture content and various other physical and chemical differences in soil, about which at present we know very little. There is a vast mass of published data bearing on these indirect causes, but it is so scattered and so contradictory in its nature that anyone who attempts to discover the truth and to separate it from the half-truths and errors has an almost hopeless task. It is intended in this bulletin to bring together in a succinct form the gist of the published literature and so to present the more important results of each article as to facilitate a comparison of their likenesses and differences. Such an extensive review of the literature of potato scab may seem superfluous; certainly it has not hitherto been made so far as the writers are aware; but it must be remembered that any presentation of new data touching its prevention which failed to take into account the conclusions of previous workers would serve more to increase the present confusion than materially to advance our knowledge. The great mass of data is especially valuable, even though it is complicated and seemingly contradictory, as it has been collected by various writers in widely different parts of the country. The then prevailing lack of knowledge as to the cause of the disease naturally lessens the value of much of the earlier writings. Much literature exists as to the cause of the disease, methods for freeing the seed tuber from the causal organism, soil treatments for the purpose of preventing the malady from developing when the organism is already present in the soil, and on the problem of securing scab-resistant varieties. The American literature has naturally been carefully reviewed; that emanating in Europe, however, is not as thoroughly presented, since much of it deals with the form which is known as powdery potato scab. The descriptions of the gross appearance of this disease resemble so closely the description of the common form of American scab that it is almost impossible to distinguish the one from the other; but the diseases are distinctly different and are produced by widely differing organisms, the powdery or European scab being caused by *Spongospora subterranea* Brunch., a myxomycete, the common American scab being caused by *Actinomyces chromogenus* Gasperini (*Oospora scabies* Thaxter), one of the thread bacteria. Not that the *Actinomyces* scab does not exist in Europe, or that the *Spongospora* scab does not exist in America. The very opposite is true. The latter unfortunately has been introduced into America and it is quite probable that the former is a native of both countries.

DESCRIPTION OF THE DISEASE

A brief introductory description will not be out of place at this point. The malady attacks the tubers during any stage of their development, from the time when they are mere buds until they cease to increase in size, but not, as some authors have believed, while they remain in the ground or after they are placed in storage. The disease first appears as a small brownish spot or stain on the surface of the potato. It was formerly supposed to originate always in the lenticels and there only, but it is shown by one of us (45) to originate on any portion of the potato, although frequently at the lenticels. It is not shown conclusively that deep scabs may arise in this way although the evidence would seem to indicate that they may. The lenticels are composed of cells similar in composition to those of the cork layer, but the intercellular spaces are large and offer an easy avenue of entrance for the fungus (figure 1). These scab spots, once started,

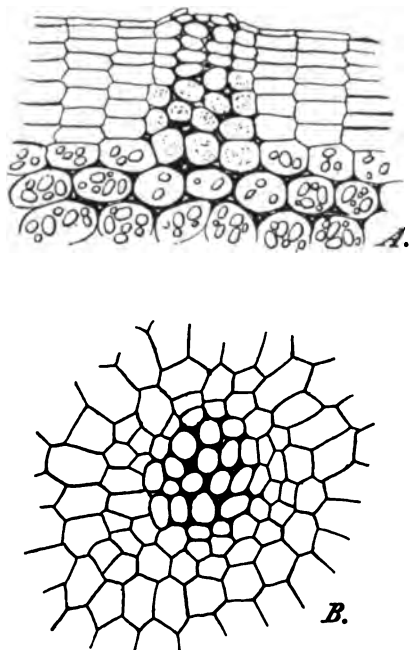


FIGURE 1.—A cross-section of a young potato lenticel. B. Surface view of same. (After Frank).

rapidly spread and increase in depth until large patches or the whole exterior of the potato may become affected, leaving very unsightly scars which, in the case of the deep or well advanced scab, may penetrate to a depth of a half-centimeter. These spots consist of

accumulated corky tissue which may be readily removed, leaving the unprotected inner parenchyma tissue exposed in a manner closely resembling the condition which exists when a scab has been removed from injured animal tissue. The diseased cells lose their starch and masses of globular bodies appear, which, according to various authors, may be disorganised tissue or fat globules (figure 2). The fact that

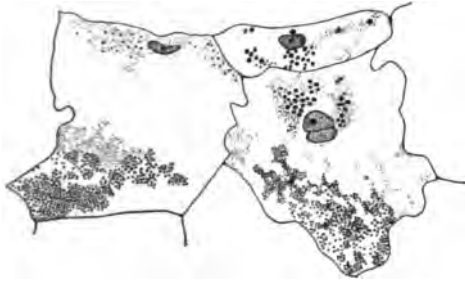
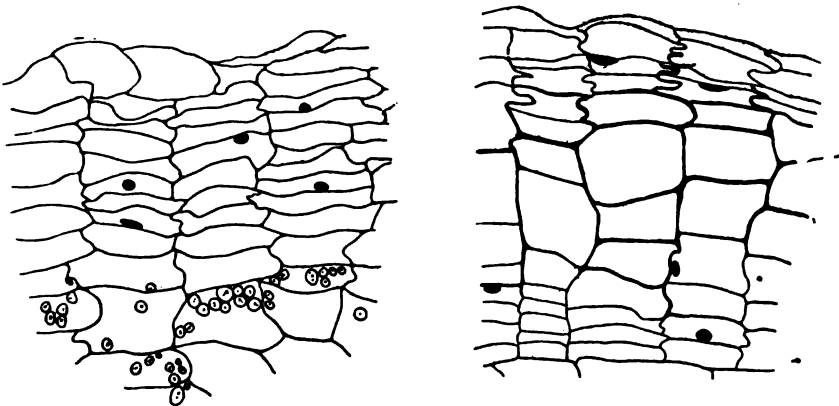


FIGURE 2.—Starch parenchyma cells containing fat droplets.

the mass of scab tissue may be eaten by wire worms or insects, and that these animals are often found in the affected spots, has given rise to the popular but erroneous impression that scabby potatoes are caused by their "bites." The scab is the result of the attempt of the cork cambium to protect the inner starch-bearing parenchyma tissue against the irritating action of the invading organism by the production of the new cork cells beneath the diseased part. The cork cells thus formed are abnormal in form and in the thickness of their walls (figures 3 and 4). Some of them are strongly hypertrophied and expanded while



FIGURES 3 AND 4.—No. 3. Section of normal potato cork layer. No. 4. Section of margin of a young scab.

others are crushed and distorted (figure 5). It would seem as though there were a series of formations of this nature in view of the fact

that the abnormal growths show more or less distinct layers. Frank and Krüger (21) claim that in certain types of scab a hyperplasia of the parenchyma underneath the cork occurs and that this bulge in the



FIGURE 5.—Section of an old scab.

starch layer causes the protuberance of the spot. They claim to be able to distinguish four different types of scab, as follows:—

- (1) Shallow scab, the diseased portion being on a level superficially with the remainder of the corky layer of the tuber.
- (2) Deep scab, the diseased tissue sinking into the body of the tuber, a hole filled with the abnormal cork being formed.
- (3) Bulging scab, wherein the abnormally stimulated parenchyma pushes the cork tissue out beyond the level of the normal skin of the tuber.
- (4) Bulging deep scab, a combination of the deep and bulging forms, wherein the parenchyma is affected at the infected areas and grows abnormally, but at the same time the cork cambium sinks into this parenchyma producing a spot which is deep but also bulges beyond the level of the surrounding cork.

The types established by Frank and Krüger are not distinct and all sorts of intermediate gradations could be picked out of a bin of scabby potatoes. Freshly dug potatoes often show the scabbed portions slightly raised above the surrounding tissue. This is due to an increase in the amount of parenchyma beneath, but after the tubers have thoroughly dried for some time in the bin this appearance is not as noticeable. The starch parenchyma also often has a water-soaked appearance under the scabs, but loses it to some extent after the tubers have been kept for a time in the open air. Varieties of potatoes differ among themselves in respect to the amount of parenchyma under the scabs and also in respect to the frequency of their formation at the lenticels. The cross-section of an old scab shown in the text figure was made from a Green Mountain potato taken from storage and represents a fairly typical condition in this variety at this time.

CHEMICAL ANALYSES OF SCABBY TISSUE.

Three analyses of the peelings from scabby and clean Green Mountain tubers were made in the chemical laboratory of this Station. In one case (No. 1) the dry tubers were cleansed by means of a thorough brushing, but in the next instance (Nos. 2 and 3) they were scrubbed with a brush and water, for the reason that it was believed that the former method did not remove all the earth from the deeper scabs. The peelings constituting the second set of samples were cut deep enough to include all the diseased tissue on the scabby tubers and as nearly as possible to the same depth on the clean ones, but the peelings representing the third set of samples were much thinner. The results of the analyses are stated on the dry matter basis as follows:—

NO. 1; THOROUGHLY BRUSHED

	Clean	Scabby
Crude ash	6.85	15.29
Crude protein	18.52	21.68
Ether extract	1.07	0.84

NOS. 2 AND 3; THOROUGHLY SCRUBBED WITH BRUSH AND WATER

	No. 2		No. 3	
	Clean	Scabby	Clean	Scabby
Crude ash	5.94	9.85	8.51	11.28
Soluble ash (in hydrochloric acid)	5.65	8.47	7.91	9.59
Insoluble ash	0.29	1.38	0.60	1.69
Lime (CaO)	0.23	0.42	0.42	0.46
Crude protein	13.80	17.88	19.26	22.05
Ether extract	0.55	1.29	1.01	1.31

These analyses show that much proteinous material, ash and fat collect in the scabby areas. The fat content is greater in the clean peelings in the first analysis but in the other two analyses more fat shows in the scabby peelings. The latter result tends to confirm the indications under the microscope which usually display cells under the scab lesions dotted with minute droplets of varying size which stain brown with osmic acid. The chemical analyses would seem to indicate that these spherical deposits are partly proteid in their nature and that they may only be impregnated with oil. The increase in ash content in the scabby peelings seems to be due partly to depositions in the cell walls as indicated by the insoluble ash and also to cell remains in the cells themselves, as found in the soluble ash. It may well be, however, that some of the deposits in the cell walls are also

Four lots of cuttings were selected, made up as follows:—(1) Clean, (2) with scabs but not in the eyes, (3) with abundant scabs around the eyes, (4) with scabs in the eyes. The average weight of the cuttings was approximately the same, varying from 13.5-14.5 grams. They were planted in the greenhouse on Feb. 17. Measurements made on March 24 of the longest shoots were:

(1)	Clean	6.35 cm.
(2)	Scabby but not in the eyes	6.14 cm.
(3)	Scabby around the eyes	7.6 cm.
(4)	Scabs in the eyes	6.6 cm.

No differences in vigor were observed but individual cuttings taken from potatoes which were entirely covered by ordinary scab failed to germinate and rotted in the soil.

There are two injuries which are undoubtedly more serious and more productive of actual loss to producer and consumer than is scab: viz., induced decay and lessened crop yield. The indirect influence of scab on rotting is readily understood when one notes how the protecting cork layer is cracked and destroyed, thus preventing it from serving its purpose of guarding the interior against the various saprophytic fungi which cause rotting both before harvest and during storage. This fact has been observed by various writers, but no definite statistics as to the extent of the resultant loss have been secured.

The penetration of the tuber by other fungi frequently occurs in badly scabbed specimens as is shown in figure 6. Bacteriological plates

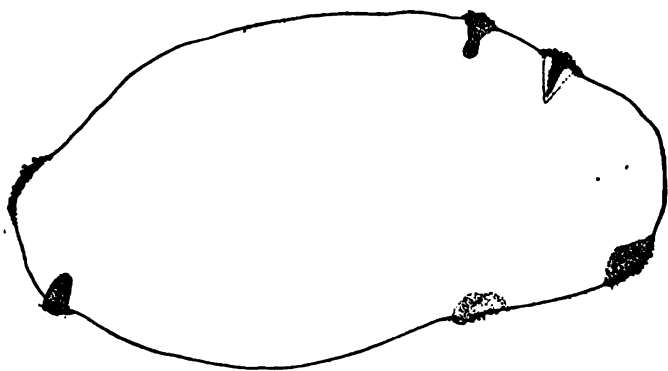


FIGURE 6.—Longitudinal section of a scabby potato showing the penetration of the tuber by other fungi following scab.

made on synthetic agar from such penetrations showed that the majority of these fungi were various forms of *Penicillium*, *Aspergillus* and *Fusarium*. These fungi rot the tuber slowly while it is held under

the consideration of numerous experiments to say that the idea is wholly erroneous. In fact the yield of any given hill is always diminished. Having during the seasons of 1889, 1890 and 1891 perfected a treatment of seed tubers in so far that a healthy product could always be grown from the most badly scabbed seed tubers available, I have been able to make accurate tests of the loss in yield occasioned by the disease. Thus using for each hill tubers of equal weight, scabbed over the entire surface, planted and cultivated under like conditions, in no case has the product from such seed untreated been equal in weight to the healthy product from similar but treated seed. A consideration of all tests made during the summers of 1891 and 1892 shows that the production from such seed is diminished by the disease an amount equivalent to a fraction over one-half pound per hill or about one-fifth to one-sixth of a crop. If three to four hundred bushels per acre be assumed a fair yield it is easy to estimate the probable loss. A disease which lessens the yield from fifty to sixty bushels per acre, aside from the fact that the entire product is made unsightly and open to excessive waste in preparation for the table, is worthy of no slight effort at prevention."

Goff, (26) planted very scabby seed and seed free from scab on a soil which had been a rich clover sod. From the former he secured a yield of 199¾ pounds and from the latter, one of 477¾ pounds.

INFLUENCE OF SCABBY SEED ON YIELDS.

(Wis. Sta. Rpt., 1892)

	Total yield in pounds	Percent scabbed	Percent slightly scabbed	Percent badly scabbed
Seed tubers free from scab..	477¾	80.6	51.0	29.6
Seed tubers very scabby.....	199¾	73.3	56.8	16.5

Many of the plants derived from the diseased seed were weak, some developed only a few stalks, and much of the seed failed to germinate. It would seem that scabbing not only weakens the vitality but is also capable of destroying the eyes or germinating power of the seed.

Trials made in this (Vermont) laboratory indicate that the seedlings are not seriously affected so far as the germination and vigor of their shoots are concerned unless the scabs are so large and abundant that all the eyes are covered. Rhizoctonia scab seems to be much more effective in preventing germination than that produced by Actinomyces, as there is a very strong tendency for the sclerotia of the former variety to collect in the eyes.

able to speak of this form of scab either as the "Actinomycosis" of the potato, or as "Corky Scab." This designation and description of the disease is important as there are prevalent at the present time in this country and in other parts of the world at least two other fairly common diseases known by the same general name of scab, viz.: *Rhizoctonia* Scab and Powdery Scab.

Rhizoctonia scab of the potato is nearly as common throughout the United States as is Actinomycosis, but may be readily distinguished from it even by a superficial examination. The spots it produces are black and hard in contrast with the brown loose-textured actinomycosis spots, while they adhere rather loosely to the corky layer of the potato. Very little penetration of the host plant seems to occur and the amount of nutrition derived from it must be relatively small. The amount of loss caused by this disease seems comparatively small throughout New England as compared to the injury and loss attributed to this fungus in the Middle and Western States. It is believed that mixed infections of *Rhizoctonia* and *Actinomyces* often occur, but the former seems to be attached to scab spots formed by the latter and to mingle its mycelium with the mass of brownish cork resulting from the stimulus of the *Actinomyces chromogenus* to the cork cambium. *Rhizoctonia* scab is produced by the sterile fungus *Rhizoctonia solani* (*Corticium vagum*).

Powdery scab of the potato has recently been introduced into Canada and the United States from Europe. It has attracted considerable attention on this side of the water and a quarantine has been established against the importation of potatoes from various parts of Canada and Europe. More recently the disease has been found by Morse (51) and by Melhus (48) to occur extensively in certain counties in Maine. Since Maine seed potatoes are used extensively in many of the states, we may expect to meet this form of scab in almost any section of this country within the next few years unless properly enforced quarantine and inspection regulations control its spread. This type of scab is so similar in superficial appearances to that produced by *Actinomyces* that it is not possible to distinguish the two apart with certainty without the help of the compound microscope. There seems in this disease to be a more definite limitation of the scabbed area, the spots have a little more the appearance of a shallow crater and the scab tissue is slightly friable. The fungus, *Spongospora subterranea*, related very closely to the slime-moulds, or possibly one of them, is the cause of this type of scab.

OTHER PLANTS SUSCEPTIBLE TO SCAB

Actinomycosis or corky scab, although primarily a potato disease, attacks other plants, as has been shown by various authors. As early as 1864 it was recognized that a similar disease of the beet was produced by the same agency, supposed to be marl. Bolley (6), after the discovery of the now recognized cause of the disease, showed by experimental inoculation that the scab of the beet was identical with that of the potato and supposed that such plants as turnip and radish might also be affected. Arthur and Golden (1), working independently, made the same observations and confirmed Bolley's findings.

Halsted (32) four years later carried on trials with various crops to determine their susceptibilities. These were planted together with potatoes in soil known to contain the scab organism. The potatoes when dug were found to be badly infected with scab. Careful examination of the several species indicated that beets, turnips and radishes were susceptible, and that four varieties of the Solanaceae, viz., *Datura stramonium*, tobacco, tomato and pepper, were not susceptible. Sweet potato, artichoke, chufa, cardoon, chickory, salsify and parsnip, all fleshy root plants, seemed free from infection.

Bolley (6) found that the disease could be conveyed to beets by growing them in soil where scabby potatoes had been grown. H. F. Johnson, working in this laboratory, has isolated organisms from scabby beets which agree in all cultural characters with those obtained by the writers from potatoes. There seems to be no reasonable doubt that the disease as it appears on potatoes and on beets is identical.

EARLY STATEMENT AS TO SCAB

Since the organism is believed to be native to the soil, and, according to our present knowledge and observation, exists almost universally in soil, especially in those which are well cultivated and rich in humus, the disease is probably as old as is potato culture. Doubtless it has existed both in America and in Europe since first potatoes were grown. And it is possible, if not indeed probable, that the disease may be common on uncultivated specimens.¹ The first mention of the disease was made in Loudon's *Encyclopedia of Agriculture* (1825) as follows: "Scab, that is to say the ulceration of the surface of the tubers, has never been explained in a satisfactory manner. Some attribute it to

¹Wright states to the authors that he observed no indications on uncultivated potatoes during his South American potato collection tour for the Federal Department of Agriculture.

the ammonia from the dung of the horse, others to alkali, and certain others to the use of wood ashes on the soil. Not using diseased seed and planting in other soil are the only known means of preventing the malady."

PLANT PARASITES AS THE CAUSE

The earlier descriptions apparently were made to fit the type then common and have little to do with that discussed in the present bulletin. It is of interest, however, to note that von Wallroth was the first to assign to the disease a fungus origin and to give that fungus a name. In 1842 he writes: "The much discussed disease of the potato discussed in economic writings I have known for a long time under the name of potato scab, potato wart, scab disease, brown stains and potato rot as a kind of vegetable rust." He supposed it to be caused by *Erysibe subterranea*, while other workers classified it as *Uredo*, *Ustilago* or *Caeama*. Von Wallroth probably had at hand the present European form caused by *Spongospora subterranea*. Many scientific workers and practical growers were inclined to question his findings and to suggest various mechanical, physical and chemical stimuli as the cause of the abnormal growths. Much experimental work was done during the succeeding half century, but relatively little advance was made other than to list the results of these numerous trials and to accumulate evidence as to the influence of lime, fertilizers, manures and various chemicals when applied to the soil or to the seed tuber. All this tended to befog the situation and to substantiate the theory generally held up to 1890, that the disease was due to some mechanical, chemical or physical cause, or to the attacks of nematodes and various insects, many of which have been described in detail.

The theory of its foreign origin disputed the field with the various irritation theories until 1886 when Brunchorst (9), describing the disease as it existed in Sweden, showed that the scab with which he worked was caused by *Spongospora subterranea*. He assumed that all forms of scab, whether of European or of American origin, were the same and caused by the same organism, while as a matter of fact he was studying only the type now known as "powdery scab." His conclusions were not fully accepted as to certain forms and it remained for Humphrey (38) in 1889 to call attention to the fact that all forms of scab were not alike. He carefully compared potatoes secured in America and from Germany through Sorauer, as well as photographs and descriptions secured from Brunchorst of the Swedish "skurv," and con-

cluded that the German "schorf" and the English and American potato scab are one and the same, but that "skurv" is a distinctly different disease and that Brunchorst's assumption that all forms are similar and caused by *Spongospora subterranea* was incorrect. This distinction, as pointed out by Humphrey, is now generally accepted.

After numerous investigators had given up the search for a parasitic cause of corky scab and after nearly every worker in this special field had announced that experimental evidence indicated that either mechanical, physical or chemical effects and not a living organism were causal, two American investigators demonstrated its parasitic origin. Despite the ample proof which their statements afforded, many were inclined at first to doubt their assertions. This is not surprising since the causal organism is so dependent upon secondary conditions present in the soil that it may not always produce the disease. It is now thoroughly recognized that a soil may be infected, even seriously infected, and that potatoes may be grown thereon without much if any danger of scab. It is also well known that under certain conditions such a soil may be induced to grow badly scabbed potatoes. This simply means that some soil amendment has brought about conditions which increase the activity of the causal organism and hence the increase of scabbiness, the amendment being the exciting but not the direct cause.

Bolley (4) by the use of bacteriological cultural methods was able to isolate from the tissue beneath the scab a bacterium which produced the disease repeatedly when inoculation were made with pure cultures and also more vigorously when infusions direct from the scab were used. The organism was a short, motile rod, varying but slightly in size, usually .7x.7-1 microns. In old cultures it appeared more spherical or coccoid, .7x.8-9. In rapidly growing cultures it was free from motion. Chains with from 4 to 6 and even 10 to 12 segments were present. In broth cultures at room temperature slight clouding appeared in from 30 to 40 hours and a pellicle formed in about 7 days. Gelatin plate cultures gave a slow growth of disc-shaped and, later, concentric colonies with a yellowish color. Gelatin stab showed a funnel-shaped liquefaction. Growth on potato and agar cultures was white and later yellow but not characteristic. The optimum temperature was from 37 to 40° C., division at this temperature taking place in from 15 to 30 minutes. The habitat of the organism was found to be the tissue beneath the potato scab lesions. Bolley speaks of its arthrosporous character and for this reason considers it a true bacterium, regardless

of its distinct motility. It is needless to discuss this organism further than to say that if it did produce scab, the disease is an unimportant type. It has not since been seen and, moreover, Bolley himself has been unable to reisolate it. His later publications lead one to believe that he doubts its importance.

Scarcely three months after the announcement of Bolley's observations, Thaxter (73) described a new fungus-like organism which he claimed was the cause of the deep form of potato scab and with which he was able to produce the disease under test conditions. While his observations did not disprove Bolley's findings, they led to quite different conclusions. It is now generally accepted, even by Bolley himself, that the organism called by Thaxter *Oospora scabies* is the chief if not the only cause of the common form of scab.

Thaxter's attention was first attracted by the presence of a peculiar gray mold-like growth on the diseased spots. From these he isolated and cultivated the organism which he characterized (74) as follows:

"*Oospora scabies*. Vegetative hyphae, brownish .06-1 microns in diameter, curving irregularly, septate or pseudoseptate, branching. Aerial hyphae at first white then gray, evanescent, breaking up into bacteria-like segments after having produced single terminal spiral spores (?) by the coiling of their free extremities. Forming a firm lichenoid pellicle on nutrient jelly and usually producing a blackish-brown discoloration of the substratum on which it grows. Causing the disease known as 'scab' on potato tubers and a similar disease of beet roots."

Thaxter's findings have been confirmed by Arthur (1) and others, including Bolley who was unable to confirm his Indiana work but readily isolated the Thaxter organism. He writes: "The first cause of deep scab as studied here is found to be a plant organism of very minute character which attacks the surface of the young growing tubers, eroding, irritating and blackening the adjacent tissue, and is identical with that associated with the disease in the east. Pure masses of the scab plant when grown on nutrient gelatin, free from all other germs, when transferred to the surface of healthy growing potato tubers will invariably produce the disease at the point of application." It is interesting to note that the potatoes from which Bolley isolated his bacterium while at Indiana were secured from the Massachusetts station and that the disease according to him was identical with the Indiana form, indicating that it was common to the East and the Middle West. One naturally queries whether there may not be

more than one form of the disease and more than one causal organism. Bolley's results suggest such a query and it may be best answered by quoting from one of his later papers (5). "As to the question whether two distinct diseases exist, I may say that I am even yet much in doubt. This would at first glance seem to imply that I doubt the accuracy of my last year's infection tests. This is, however, in no wise necessarily so, as various other circumstances are involved which render such an assumption on my part as yet comparatively groundless. Certainly, in common with those conversant with the details of such work, I recognize that there are many possibilities of error; but that work was too carefully done to admit of any change in the assertion made in the report of the same, other than in so far as they assume only one form of the disease, a point which with me must remain in doubt until I have been able to do work under conditions similar to those under which the work was then carried out. The organism with which I then worked, a true bacterium, was undoubtedly very different from that pointed out by Dr. Thaxter as the originator of 'deep scab,' the one which upon coming to Dakota I was immediately and readily able to recognize as the active agent in the disease here. Furthermore, in so far as cultural characters and infection tests have been conducted this year, affirmative results have been attained only with the latter form, the bacterium not being found. I have, to that end, to date used only the disease as found here, a form very much more pronounced than that studied last year, possessing some characters of action not then noticed. How many of these were present but not then noticed, and how much they are due to soil differences, I can not say. Certain it is that it is hard to draw the line between the surface and deep form of the disease, from a consideration only of gross characteristics unless it be in the pink coloration of the surrounding living tissue not then noticed.¹

That, in the Indiana work, I many times under apparent exclusive infection conditions induced potato scabs, recognized as such by all who saw them, there is no question. Considering then for the time that the disease as generally understood has but one origin, there are two possible ways for accounting for those results: First—Error in formation of the infection material so that other germs than the bacterium were present (possible but not probable); Second—That the

¹The writers have repeatedly observed all stages of surface and deep scab in the same field, in the same hill and on the same potato. It is barely possible that the surface and deep forms may be caused by different strains of the same organism, some more active or virulent than others, or that early infection or peculiar soil conditions in the immediate neighborhood of the lesion may have brought about the difference.

bacterium used (which was undoubtedly parasitic in the potato plant) might under the conditions of the inoculations produce the scabbing which in nature would not occur. This I deem very probable from the then determined capabilities of the bacterium to penetrate living tissues of the plant even to parts of the young growing stem. The question is yet an open one. I can only regret that my authentic material was unavoidably lost and await opportunity to give it further tests. I may say, however, that the parasite studied this year acts much more rapidly in artificial infection than did the bacterium and there is little question that it is the originator of the chief amount of potato scab."

With the discovery of a parasitic cause of the disease, renewed attempts were made to prevent the spread of scab by means of tuber disinfection. This procedure has been fairly successful, formaldehyde being used for the purpose as a gas and as a weak solution in water. Other chemicals have been used but less extensively. Many workers have contributed to perfecting this method, but much of the credit is due Bolley (5) for so ably presenting it to the popular mind.

OTHER THEORIES REGARDING THE CAUSE OF SCAB

While the individual theories advanced as to the cause of potato scab are almost as many as the men who have investigated the subject, they naturally group under four heads, viz.: (1) Mechanical irritation; (2) insect and other animal parasites; (3) chemical erosion or irritation; (4) excessive moisture. It is now clearly understood that these are not direct causes, yet they may be considered as secondary, conditional, indirect causes; that is to say they are conditions which tend to favor the growth and to accentuate the effects produced by the direct cause, the organism. The influence of these conditions is so important that stress may well be laid upon these secondary causes.

Mechanical irritation: The theory that scab was a resultant of mechanical irritation was based on popular observation and lacks any considerable volume of experimental evidence. It having been noted that soils containing such materials as lime, rubbish, builders' refuse, refuse from ash-pits, street sweepings, and similar materials were apt to produce badly scabbed potatoes, it was reasoned that these were cause and effect. Smith (62), the chief advocate of this theory, agreed that these substances caused mechanical injury by producing a thick corky layer. He states that "on visiting this position (where diseased tubers are found) the irritating substance in the soil will usually be seen."

Insect and other animal parasites: This theory is based largely on the fact that insects of various species, nematode worms, wire worms, etc., are often found feeding on diseased potatoes, many of them seeming to prefer the diseased or decaying tissue. Beckwith (2) placed several dozen millipedes in a glass vessel containing growing potatoes and concluded that "millipedes do not feed upon sound tubers, their food consists of decaying vegetable matter. The presence of millipedes in the hill with scab tubers was due to the scab, they being attracted by the decayed portion which they desired for food and the scab is not due to their presence." Hopkins (36, 37) also describes a beetle *Epidapus scabies*, which he claims is capable of causing scab. The injury produced by these insects is, however, of the nature of erosions of the tuber surface which sometimes so closely resemble the common form as to pass for it. Orton (55) discusses a disease due to the attacks of ellworms, *Heterodera radicola*, in the western and southern states, which might be confused with potato scab.

Chemical erosion or irritation: This theory has more or less in common with the mechanical theory in that the chemical action of certain substances is held to cause the potato to produce an abnormal quantity of cork cells. It was believed that this was brought about by the caustic action of lime, ashes and various fertilizers. The use of barnyard manure and of marl and lime has long been popularly associated with potato scab. As early as 1864 farmers and practical growers so explained the disease and believed that the scabbing following liming did not reach its maximum until 10 years after its application.

There is a strong likelihood, almost certainty, that these substances do tend to encourage scabbing where the organism is present, because of their tendency to correct acidity and because the scab organism requires a slightly alkaline or nearly neutral medium in order to thrive. This theory was further supported by Humphrey (38) who says: "Several years' observation at this station (Massachusetts) points also to the correctness of the view that the cause of our trouble is to be sought in peculiar physical or chemical conditions of the soil." In this connection see Sorauer's statement on pages 22 and 23.

Excessive moisture: This theory is based upon the fact that moisture on the lenticels tends to produce an abnormal growth of corky tissue at such points and that the actual amount of scabbing on potatoes grown on wet soils is greater than those grown on dry soils. According to this theory Caspari (10) supposed that the disease was induced by the action of moisture on the lenticels. They increase in

size and finally burst the cork rind, thus giving rise to the formation of scab, or, rather, to a structure capable of producing scab. These tissues continue to degenerate underneath the cork so that a more or less thick scab is produced, due to the replacement of the starch cells by the cork cells forming the lenticel. Scab due to a local increase in the cork formation, does not occur in the wart or on tubers produced in the air. Later Stahl in 1879 shows that if transpiration is stopped the lenticels increase and may develop into scab spots. Among the earlier advocates of this theory was Schacht (60) who says: "As the lenticels develop by the formation of new cork cells they break through the skin and are transformed into irregular cavities with ragged borders or long irregular cracks which are always lined with a layer of cork. . . . I must here regard heavy moisture of rich soil the first cause." Frank (20) and Giersberg (25) also support the excessive moisture theory. Beckwith (2) concluded that irrigation during a dry season increased scabbing, in one test from 31 to 48 percent, in a second test, where barnyard manure was also added, from 22 to 71 percent, while when barnyard manure was used without irrigation scabbiness increased only from 21 to 30 percent. Numerous other citations of a similar nature might be made. Apparently excessive moisture does tend materially to increase scabbing, but it must be remembered that it is only a secondary cause inducing but not producing scab.

The early theories held in Europe regarding the cause of scab are carefully and briefly reviewed by Sorauer (63) and direct translation seems in place. In discussing the influence of moisture on the lenticels relative to the production of scab, he writes:

"That this hypertrophied formation of lenticels is dependent upon an unusual amount of moisture we conclude from the following facts: During a long continued season of wet weather the lenticels of alder trees stand out in the form of thick white protuberances; by immersing a piece of cherry stem in water a luxuriant growth of cork can be artificially produced; finally, in case of the potato, these cork warts may be actually produced by keeping the potato for a long time in moist air. Nobbe found, by a water culture of the potato, that the tubers grown in water produced small warts while still very young. These warts were caused by a local increase in growth in the cork formation, and were not present in tubers produced in the air.

The view that superfluous moisture at an unseasonable time is the cause of the increased growth of cork that produces scab is indorsed by Caspari and Schacht as well as by Frank. A later work by Stahl established the fact that if transpiration is stopped, lenticels develop beneath the stomata. On the contrary, farmers assert that in the majority of cases the adding of lime and marl to the soil, and manuring with dung and street sweepings causes the disease. Kühn agrees with Wallroth in the opinion that the formation of scab is caused by a fungous growth (*Erysibe subterranea*, Wallr.).

On the other hand, iron, when present in a low state of oxidation, is considered injurious. In a field of potatoes at Newmarket three rows which had been marled with light colored earth mixed with iron oxide were found free from scab, while the rows that had received marl that was dark colored from the presence of peroxide of iron were very scabby.

The assertion has frequently been made by practical farmers that fresh animal manure causes scab, especially in the thin-skinned varieties, and that the disease makes its appearance after an application of soapsuds, while after a strong application of potash, which had proved very injurious at another time, the tubers were free from scab.

I believe that Wallroth's opinion is erroneous. It is true we find fungous formations upon the dead parts, but none that attack healthy tissues. Many have objected to the view that scab is caused by adding lime, marl, or dung to the soil, but when it comes to final definite results, the reports vary in regard to secondary circumstances. For example, one person says that scab made its appearance after the application of marl, but that the greatest development of the disease did not occur the first year, during which the potatoes were perfectly healthy, but that the disease steadily increased during the ten following years. The same account claims that beets are similarly affected by marl. It is interesting to note that where the marl was not used the potatoes showed no scab. In Posnia, in the seventeenth century, marl was frequently added to the loose soil of large estates for the purpose of raising *Medicago media*. This was generally preceded by two crops of potatoes, which were always marled. In spite of this, scab never made its appearance if the marl was drawn before winter and thoroughly mixed with the soil. The same experiment was recorded a year earlier in Saxony in the *Zeitschrift des Landwirthsch. Centralvereins* (p. 219).

Helden reports a very thorough experiment at Pommritz in regard to the use of lime. A piece of new land was given heavy applications of lime (3,600 pounds to the acre), six times between 1868 and 1878, and in 1878 the land bore potatoes after a fresh application. The potatoes when gathered were completely free from scab. It will be seen that in this ground there was lime of different ages, from the fresh to that ten years old, and no injury resulted.

Contradictory as these results appear, they may nevertheless be harmonized if the theory should be confirmed that the frequently occurring secondary action of lime may be the dangerous agent that causes the death of the growing cork cells. Helden directs attention to the fact that the ammonia already contained in humus is set free by the lime when a great deal of lime is used, and that the soil is not at that time able to absorb all the ammonia that is set free, a part of it escaping. This surplus ammonia will be very apt to destroy the loose cork cells within the lenticels and cause the cork formation to penetrate farther into the tissues. The ammonia will become harmless only when oxidized into nitric acid, and we have a positive statement in this direction. Kraus-Kriesdorf mentions the experiments of Dr. Schreiner, who found that scabby potatoes were very abundant in almost pure quartz sand which had been manured with ashes, pulverized turf, and nitrogen in the form of ammonia; but when in the form of nitric acid no such effect was produced. A quartz sand, without manuring, or with the ashes alone, did not produce scabby tubers, even when mingled with turf. Iron filings, iron oxide (turf ashes rich in iron) may perhaps act indirectly by checking the formation of nitric acid."

THE RELATIONSHIP OF THE POTATO SCAB ORGANISM TO THE HIGHER BACTERIA

A study made at this Station of the organism causing the corky scab of potato, *Oospora scabies* Thaxter, has resulted in the conclusion that it is related to the higher bacteria. This view was originally suggested by the resemblance of its cultural and morphological characters to those of soil organisms of the *Streptothrix* type. This view

was expressed in a paper read by one of us (G. C. C.) before the American Phytopathological Society in 1911 and has since been accepted by various workers.

A large number of organisms of the *Actinomyces* type have been isolated at this Station from soil, potato scab, and various other sources. Many of the available species of this group have also been secured from Kral's laboratory and are under study. Some of the organisms were isolated from potatoes secured from England, Holland, Belgium and Germany and three strains were isolated by one of us (B. F. L.) in Germany and were sent to this laboratory as pure cultures. A careful laboratory study of these organisms isolated from the potato scab shows them to be identical in every characteristic but one (that of spore formation in a few strains) with the organism described by Thaxter as the cause of the disease. The organisms have been isolated on various media, chiefly plain agar, Clinton's lima bean agar, potato peptone agar and potato glucose agar, all of which are alkaline or, at least, only slightly acid.

In the following description of the cultural characters of the causal organism, cultures from four sources were used. These were designated as Nos. 1, 150, 151 and 14. Nos. 1 and 14 were isolated from Vermont potatoes in this laboratory; No. 150 was obtained from tubers at Bonn, Germany and was isolated in the laboratory of the Botanical Institute of the Poppelsdorfer Agricultural College; No. 151 was isolated at the Biologische Anstalt at Dahlem near Berlin from potatoes grown in the garden of that institution. The minor differences noted between these strains will be found in the following description of cultural characters. All were found capable of producing scab on inoculation. Numerous other cultures in addition to these four were carried through the bacteriological chart, but the four strains named were selected for this description.

SUMMARY OF CHARACTERS OF *ACTINOMYCES CHROMOGENUS*

I. OCCURRENCE AND IMPORTANCE

The organism occurs in the soil and is the cause of potato scab as described by Humphrey (38), Thaxter (73) and Bolley (3). An increased cork formation results in a surface or deep scar resembling a scab. The organism is known to cause the potato scab in Europe, America, Australia and Africa. It may be found living saprophytically in most soils but is more abundant in soils rich in humus and those with an alkaline reaction.

II MORPHOLOGY

1. *Form*,—a thread or filament .05 to 1 microns in diameter, long and branched, wavy or curved, irregularly segmented and capable of forming aerial hyphae which break up into gonidia or short cells resembling bacilli.

2. *Endospores*,—not found; no indications that they are ever produced.

3. *Gonidia*,—short segments of the hyphae or mycelium form by the segmentation of any part of the mycelium either in the depth of the medium or on the surface, usually more abundant on the surface, giving the colony an ashy gray, cretaceous appearance; not always present and usually more common in older cultures.

4. *Motility*,—non-motile.

5. *Capsule or sheath*,—both absent.

6. *Involution forms*,—a tendency to produce aerial gonidia is present in old cultures; the mycelium also becomes degenerated and contains granules which stain deeply while the mycelium does not stain readily.

7. *Staining reactions*,—organisms stain readily with the ordinary stains, negative to Ziehl-Nielsen's acid-fast stain, positive to Gram's stain.

III. CULTURAL CHARACTERS

1. *Agar stroke*,—growth slow, abundant, spreading, flat raised, contoured, rugose, verrucose, opaque to translucent and straw-colored, coriaceous; medium browned.

2. *Agar plate*,—growth slow, round, irregular, lichenoid, contoured, rugose, raised, umbonate, entire, filamentous and, later, amorphous; medium browned.

3. *Agar stab*,—abundant at top, slight along line of puncture as beaded colonies.

4. *Gelatin stab*,—growth slow, best at top, very little along the line of puncture, beaded; liquefaction saccate to statiform, beginning in 5 to 10 days and continuing very slowly.

5. *Gelatin*,—same as agar colonies.

6. *Nutrient broth*,—growth at the surface and slow, ring and later pellicle formation; sediment abundant, compact, and flocculent; broth never clouded.

7. *Potato plugs cooked*,—growth slow but abundant, spreading, flat, raised, umbonate, contoured, rugose, glistening, some strains creta-

ceous, thick and coriaceous; color of growth and potato a dark gray to almost black.

8. *Plain milk*,—growth slow and at the surface as a ring and a wrinkled pellicle; milk slowly digested without coagulum, browned and turned alkaline.

9. *Litmus milk*,—litmus intensified, turned to a tea-brown, slightly and slowly digested; sometimes acid is produced.

10. *Turnip plugs cooked*,—growth slow at first, abundant, spreading and beaded, flat raised, verrucose, umbonate, glistening; other strains cretaceous; color creamy, orange to greenish gray, coriaceous; turnip may or may not be slightly browned.

11. *Carrot plugs cooked*,—growth slow, abundant, resembling growth on turnips.

12. *Beet plugs cooked*,—growth neither so rapid nor so abundant as on turnips, and darker.

IV. PHYSICAL AND BIOCHEMICAL CHARACTERS

1. *Indol production*,—generally absent.

2. *Acid production*,—negative or seldom produced.

3. *Ammonia production*,—moderate quantity, varying from 8 to 12 cc. in terms of N/1 HCl per litre.

4. *Gas production*,—negative.

5. *Toleration to acids and alkalis*,—best growth in slightly acid or neutral medium; quite sensitive to larger quantities of either acid or alkalis.

6. *Temperature*,—best growth at 25° C., slow growth below 18° and above 37½°; thermal death points: No. 1, 50-54° C., No. 14, 49-50° C.; No. 150, 49-51° C.; No. 151, 50-51° C.

DETAILED DESCRIPTION

MORPHOLOGY

Form of filaments: On the common forms of culture media the morphology is quite consistent, the organism appearing as long irregular filaments (figure 7), the branches interlacing to form at first a gelatinous mass which soon becomes tough and leathery. The diameter varies slightly from .5 to 1 micron, but the length naturally displays great variation. At first few segments can be observed, but on dry media, or in older cultures, the septae are more numerous. The aerial gonidia which are formed are segments of the filaments separ-

ated by crosswalls from ordinary hyphae. The segmentation of the filaments is observed with difficulty in water mounts, the cross walls in the filament being scarcely visible or not at all, while the segmentation where gonidia are produced may be readily observed. The septae are seen more distinctly after staining with such stains as carbol-fuchsin and Sterling's gentian violet, followed by a partial decoloration with alcohol. Thaxter observed segmentation after staining with iodine. Under unfavorable conditions and in old cultures the protoplasm is often more or less disintegrated, similar to that observed in old cultures of *Mycobacterium tuberculosis* and *Pseudomonas radicola*.

Aerial gonidia and spores: True spores have never been observed. The bodies which Thaxter mentions as possible resting spores have not been observed. He may have mistaken for these bodies the curved ends



FIGURE 7.—Drawings of the organism *Actinomyces chromogenus* of potato scab, showing the branching and irregular segmentation. Groups of gonidia are shown in lower right hand corner. Magnified about 900 diameters.

and the angles of filaments which, when viewed under the microscope, appear swollen and refractive and resemble resting spores. This appearance has been observed but no true spores have been seen.

A study of a large number of strains shows that some strains or species of this organism produce aerial hyphae and gonidia, as they have been called by some writers; that is, under certain conditions, such as lack of moisture or concentrated medium, the mycelium grows up out of the medium and becomes closely segmented into short rods resembling rod-shaped bacteria. Thaxter (73) writes: "Under certain conditions these filaments may grow up into the air and become spirally coiled at their extremities and subsequently rather closely septate, may break up into short pieces resembling bacteria, at the same time turn-

ing from white to gray." These segments do not have the function or the nature of spores but simply serve as a segment of the mycelium, which by increasing the number of segments may increase the chances for spread and for continuous existence. "This fructification may make its appearance at points on many solid media especially when the latter has become somewhat dry." We have also observed aerial gonidia on some strains growing on milk and various forms of broth, so that we are safe in saying that a lack of moisture is not the only factor controlling the production of these segments.

The formation of aerial gonidia depends to quite a large extent on the strains of the organism; some produce them quite abundantly and in fairly young cultures, while others never produce aerial hyphae or gonidia, or, if so, rarely and under exceptional conditions such as have not obtained here. The original cultures which were first studied, and many other strains now in our possession, have not been known to produce dry aerial growth, with the exception of one strain on a 2 percent lactose agar medium, and it is even doubtful whether or not aerial hyphae were observed at that time. Certainly aerial hyphae or gonidia have not been produced within the last two years while these organisms have been under constant observation on various culture media. On the other hand many strains have been isolated from potato scab, etc., which upon reinoculation quickly produce scab and which show an abundance of the gonidia on practically all common forms of culture media. This is particularly true of three strains, Nos. 150, 151 and 14. The color of this cretaceous surface growth when present varies considerably with different organisms and with the age of growth. With some it is always a pure white or it may be a dark ashy gray; in other cases it may be white at first, gradually turning a dark ashy gray as the culture becomes old. In some other chromogenic species, not known to produce scab, the cretaceous growth may be blue, orange, red, yellow, etc., depending on the species. Repeated inoculations have shown that both the cretaceous and the non-cretaceous strains are capable of producing potato scab and with almost equal virulence. This study of a large number of strains isolated from various sources shows that some produce gonidia more readily than others and that cultures may be selected representing a succession of types from those producing no gonidia through those showing a moderate amount to those producing an abundance of gonidia. Several show gonidia only at a raised point or at the top of the agar slant where the medium is comparatively dry.

These gonidia-like bodies do not resemble spores but they may take the place of true fruiting bodies. They are readily brushed off and broken up and are easily scattered by the wind, or distributed by the soil water. This is an important characteristic since the mycelium generally forms a tough, leathery mass, at least when growing under artificial conditions. The thermal death point is the same as that for the mycelium, contrary to the work of Lachner-Sandoval, Neukirch, Rullmann and others, who claim that these aerial segments show a higher thermal death point than the mycelium. We have found that there is little or no difference between the thermal death point of the mycelium and that of the aerial segments. Further work on this point is desirable.

Capsule or sheath: A capsule or sheath has not been observed, but it is possible that the ends of the filaments may become swollen as commonly found in *Actinomyces bovis*.

Motility: Flagellae are absent and motility was not observed.

Involution forms: No important involutions have been observed, except a greater amount of segmentation and an apparent degeneration of the protoplasm which takes on a granular appearance as shown in figure 7. This granulation of the protoplasm is more readily and more deeply stained than the remaining mycelium.

Staining reactions: The staining of the organisms offer no special features of interest. Preparation from young and old cultures offer similar reactions towards stains with the exception that the staining of older cultures brings out the granular particles more strongly. The organism stains comparatively well with all watery solutions of anilin dyes, carbol-fuchsin and Sterling's gentian violet. It gives a negative reaction to Ziehl-Nielsen's acid-fast stain but a positive reaction to the Gram stain. It is, however, decolorized by prolonged exposure to alcohol.

CULTURAL CHARACTERS

Method of transferring the inoculum: Owing to the tough and coriaceous nature of the group of organisms it is impossible to make transfers by the same methods as are adopted in cultivating the lower or true bacteria, such as by the loop and needle, and secure uniform results. It is impossible to transfer inoculums directly from most cultures by the loop or needle except where aerial gonidia are present. Hence a method which could be used with all cultures was adopted. This consists of transferring a colony or a portion from the culture,

usually an agar stroke culture, to a sterile petri dish and then reducing it to fine particles by mashing with a stiff, heavy (no. 15 gage), flattened platinum needle. This material was then transferred to a tube of sterile water and the inoculations made therefrom by means of sterile pipettes instead of an ordinary loop, one or two drops of the suspension being used. Stab cultures were made with a platinum loop instead of the platinum needle, since the needle seldom carried sufficient to inoculate the medium to any appreciable depth. Even by this method we believe that the inoculations used were not larger than those usually made by the ordinary methods when working with the lower bacteria. Pipettes always took the place of loops and loops always took the place of needles when transferring the finely ground suspension inoculum as prepared above.

Agar stroke: At 25° C. growth appears in 48 hours as visible, straw colored, punctiform colonies, gradually becoming more abundant and spreading over the surface or developing as raised colonies, contoured, rugose to verrucose. All colonies are at first glistening, some strains becoming dull and many becoming cretaceous. The growth is white to straw color and opalescent to opaque; it is thick and tough or coriaceous, requiring a stiff needle to break it up. The medium becomes brown after a few days and gradually diffuses throughout the whole tube. Strain No. 1 never shows cretaceous growth on the surface; No. 14 shows a small quantity after a few days.

Agar plate colonies: Colonies at 25° C. show slow growth, the surface ones developing more rapidly than the deep colonies. The shape at first may be round or irregular depending on the shape and size of the parent particle from which the colony developed. As the colonies grow older they become round, entire, rarely irregular. The surface at first is smooth and lies flat on the medium, later becomes lichenoid, raised, pulvinate or umbonate; in some strains where aerial gonidia are produced concentric rings appear. At times the growth may become undulated and even folded, forming a very much wrinkled colony, the surface ones developing more rapidly than do the deep colonies. The edge is usually entire and filamentous. The internal structure appears amorphous in the denser part of the center, gradually passing to a thinner, filamentous outer edge. See plates V and VI.

The medium becomes brown shortly after growth appears, in from 36 to 48 hours, and continues to increase and spread, discoloring the agar in the neighborhood of the colony until growth ceases. This

browning is of much value in identifying the organism when isolating it from potato scab, soil and other sources. The cretaceous growth in some strains or species appears in from 5 to 10 days, usually in the center of the colony and gradually covering the whole surface, or it may appear as in No. 14 as concentric rings. Cretaceous growth never appeared on No. 1 which is looked upon as the typical organism. The size of the colony varies widely from 2 mm. to as large as 10 to 12 mm., sometimes becoming raised 1 to 2 mm. above the surface of the medium. Some colonies after several days growth crack or break open in various shapes, the crack being in the center and forming a triangle or starlike rupture.

Agar stab: Growth at 25° C. usually appears in 24 to 48 hours, accompanied by browning of the medium. It is abundant and best at the top, very little growth occurring along the line of puncture, as small, white, scattered filamentous colonies. Abundant growth develops on the surface, as a thick, contoured, lichenoid colony or colonies spreading over the whole surface. The growth is straw color. Cultures of Nos. 14, 150 and 151 rarely becomes cretaceous on the surface, No. 1 never. See plate XII.

Gelatin colonies: Plate cultures develop slowly, producing visible colonies in 48 to 72 hours. The colonies resemble those on agar, but are more raised and umbonate, or at times spreading. Liquefaction proceeds very slowly in the neighborhood of the colony, beginning in 5 to 10 days. Aerial growth is seldom secured even with those strains producing aerial segments abundantly on other media. Browning of the medium appears as soon as growth is visible and discolors the medium for a considerable distance from the colony.

Gelatin stab: Growth is best and abundant at the point of inoculation, appearing as a large, spreading, contoured colony. There is little or no growth along the line of inoculation, but when present it is beaded or as scattered filamentous colonies. Liquefaction is saccate to stratiform, beginning in 5 to 6 days and usually complete in from 3 to 4 weeks. Liquefaction progresses slowly and, unless precautions are taken to prevent evaporation, the digested medium evaporates as rapidly as it liquefies, leaving a thick syrupy material in the bottom of the tube. Digestion is accompanied by a deep browning, so that the medium is a very dark brown after a few week's development.

Nutrient broth: Growth is comparatively slow, appearing in 40 to 48 hours as very small compact colonies forming a ring attached to

the glass walls of the tube, as a flocculent suspension, or as a fine, flocculent precipitate. The ring begins to form in 4 or 5 days but may continue to form for a long period, until a complete pellicle is formed. The ring consists of loosely connected filamentous colonies which soon fuse, forming a ring of dense, thick, coriaceous mass, in some cases amounting to a complete pellicle. The ring or pellicle is easily set free from the glass tube by agitation and sinks to the bottom. Some times it becomes free of itself and settles, after which another ring or pellicle may form. Growth may continue to form and then settle to the bottom in this way for several weeks until a large quantity of precipitate has collected. The suspended growths which form beneath the surface of the broth are white, filamentous, ball-like and distinctly nucleate colonies and in some cultures concentric rings may be observed. When resting on any solid substance the growth takes the shape of a hemisphere but is always loose and filamentous. The medium never becomes cloudy, always remaining clear even after several months of growth. From the very beginning of growth a brown stain is produced which discolors the medium, close to the surface at first but gradually diffusing throughout the broth. Very little or no growth takes place in the lower part of the medium, the abundant growth always developing close to the surface. See plate X.

Carbohydrate broths: The influence of various carbohydrates on the rate and nature of growth was studied by making up broths containing 2% of the desired sugar, save that in the case of glycerin 5% was used. Dextrose, sucrose, lactose, manite, maltose and glycerin were used. These substances have but a slight influence on the organism and it seems advisable to record only the fact that the general reactions are not different in essentials from those observed when plain broth is employed.

Yolk of egg: The yellow of six eggs is carefully separated from the white, thoroughly mixed, poured into test tubes to a depth of 1½ inches, placed in the autoclave at a suitable slant and steamed for 10 minutes at 5 pounds pressure. Twenty-four hours after inoculation the egg shows black stains at various points and by 48 hours very dark brown colonies can be seen in the center of the stained areas. The growth continues and by 5 days the surface is covered by a mass of small united colonies, raised and contoured, giving the whole growth a rugose appearance. The egg stains a dull dark brown. No further important characteristics are observed even after



PLATE I.—Potatoes affected by the ordinary scab due to *Actinomyces chromogenus*.



PLATE II.—Potatoes affected by the black or *Rhizoctonia* scab.



PLATE III. Tuber affected by *Spongospora subterranea*, commonly named "powdery scab." X Scabs unbroken, covered with the epidermis. ° The membranous epidermis lifted up with a pin, showing spore powder. || Two scabs minus the spore powder which form "craters" similar to ordinary scab. (Photo, courtesy of Dr. H. T. Güssow).

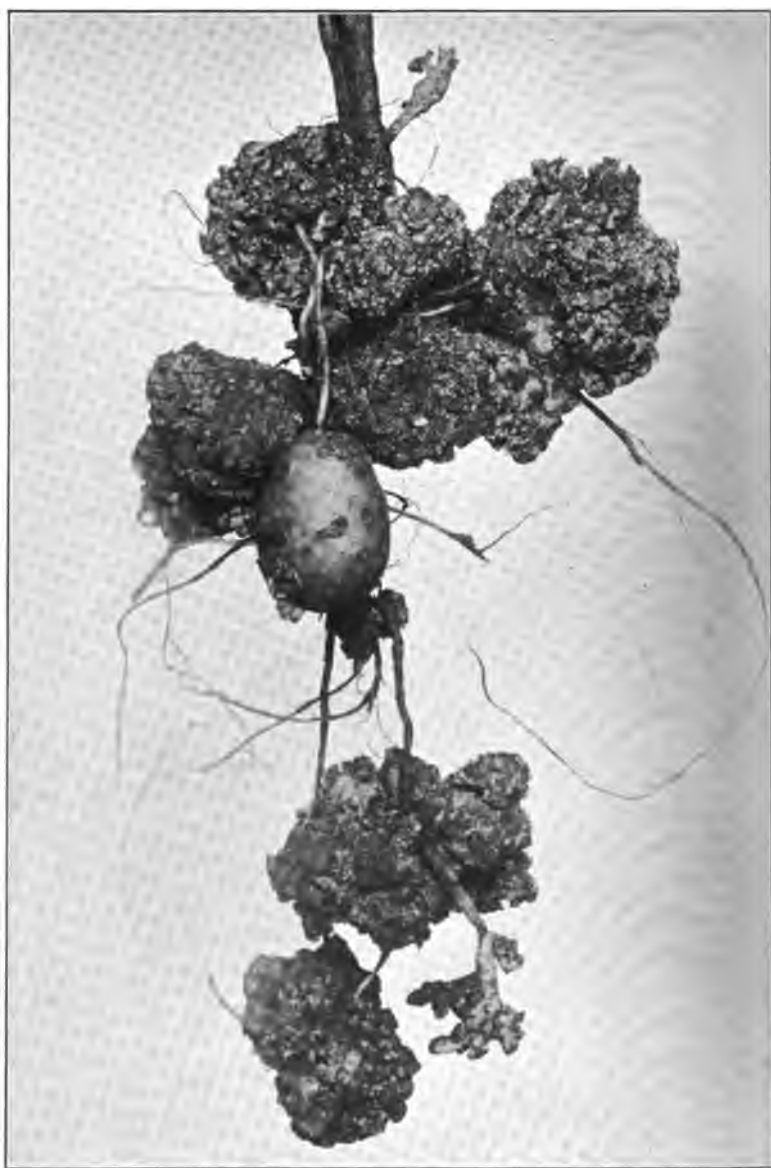


PLATE IV.—Whole plant (portion below ground only) of a potato infected with *Chrysophlyctis*, commonly called "potato canker." (Photo, courtesy of Dr. H. T. Güssow).



PLATE V.—Colonies of the four strains of the potato scab organism, *Actinomyces chromogenus*, used in determining the cultural characters.

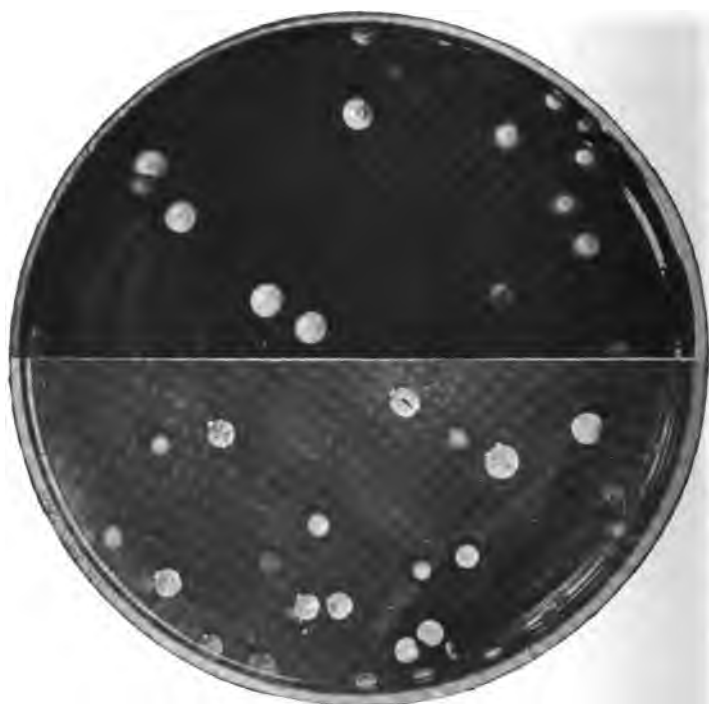
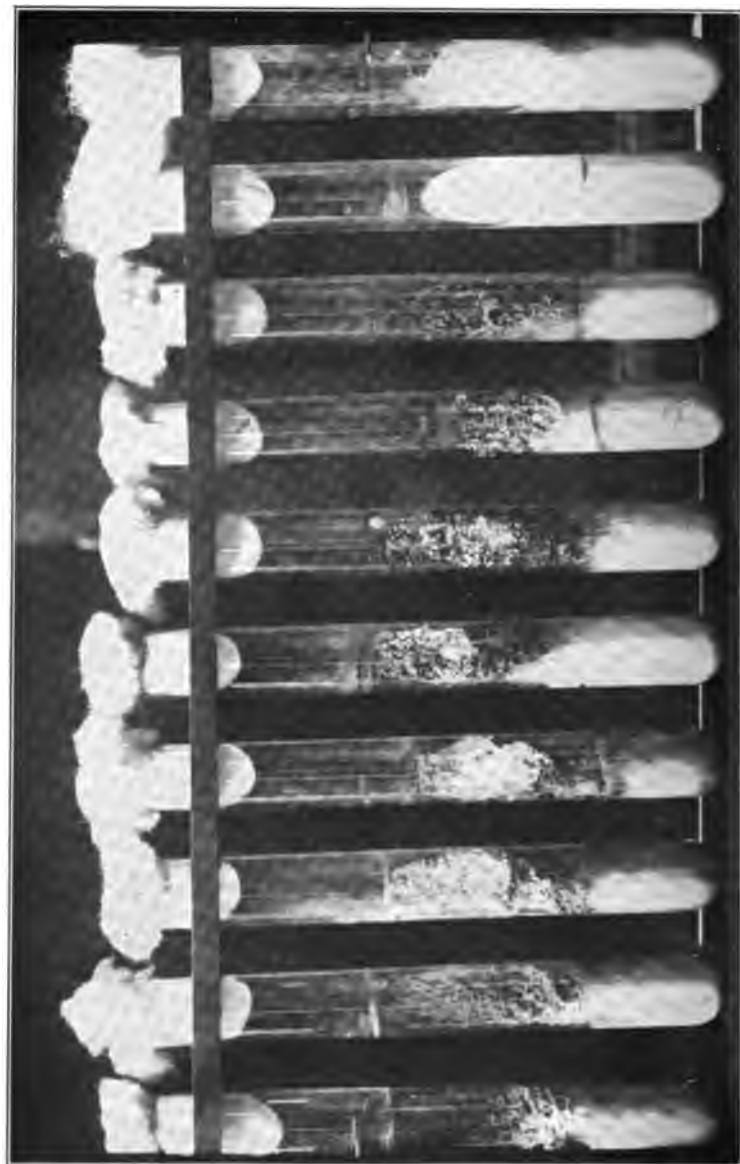


PLATE VI.—Colonies of two of the strains of this organism on plain agar. The upper one shows the umbonate appearance which the colonies often show; the lower one shows radial cracking of the colonies.



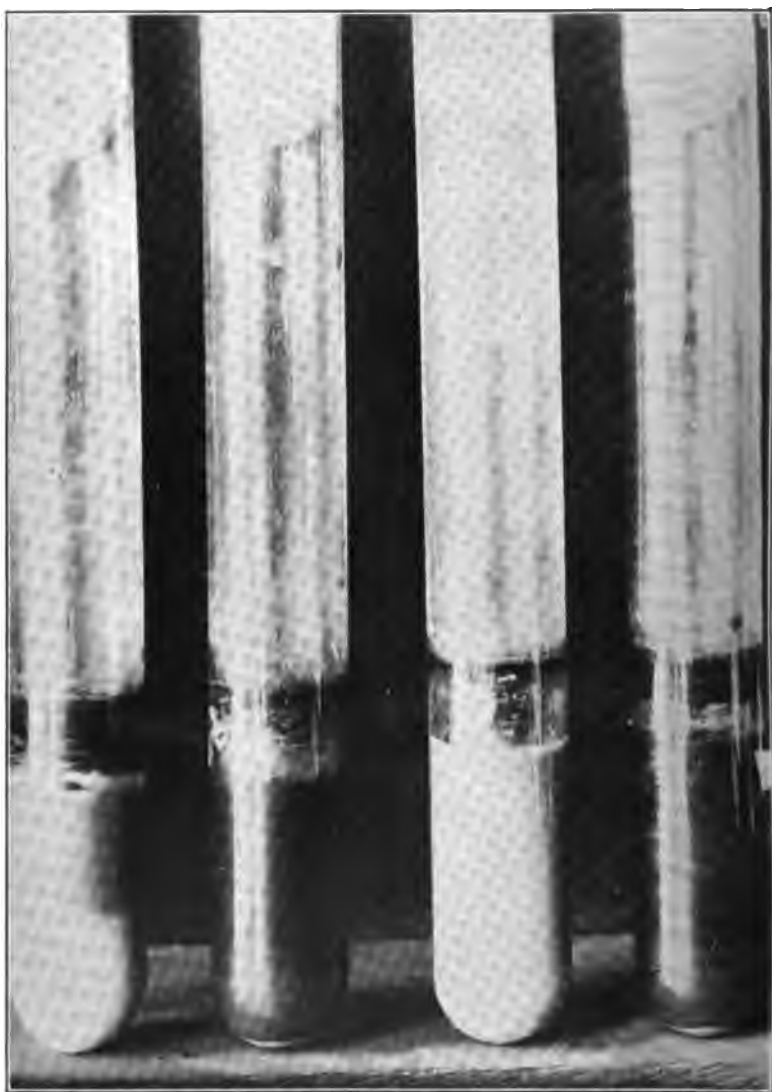
No. 1. No. 150 No. 151 No. 14
 PLATE VII.—Cultures of *Actinomyces chromogenus* on potato 2% glucose agar.



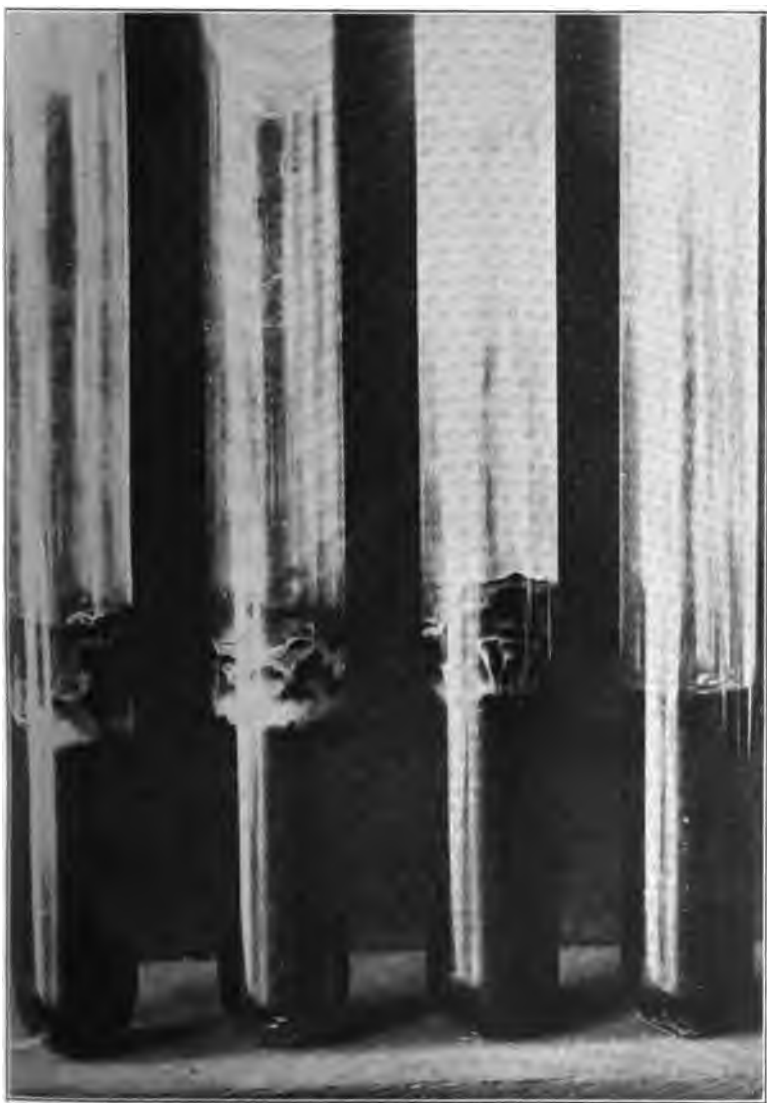
No. 1 No. 150 No. 151 No. 14 Check
PLATE VIII.—Cultures of *Actinomyces chromogenus* on cooked potato plugs.



No. 1 No. 150 No. 151 No. 14
PLATE IX.—Cultures of *Actinomyces chromogenus* on cooked turnip plugs.



No. 1 No. 150 No. 151 No. 14
PLATE X.—Cultures of *Actinomyces chromogenus* on maltose broth.



No. 1 No. 150 No. 151 No. 14
PLATE XI.—Cultures of *Actinomyces chromogenus* on plain milk.

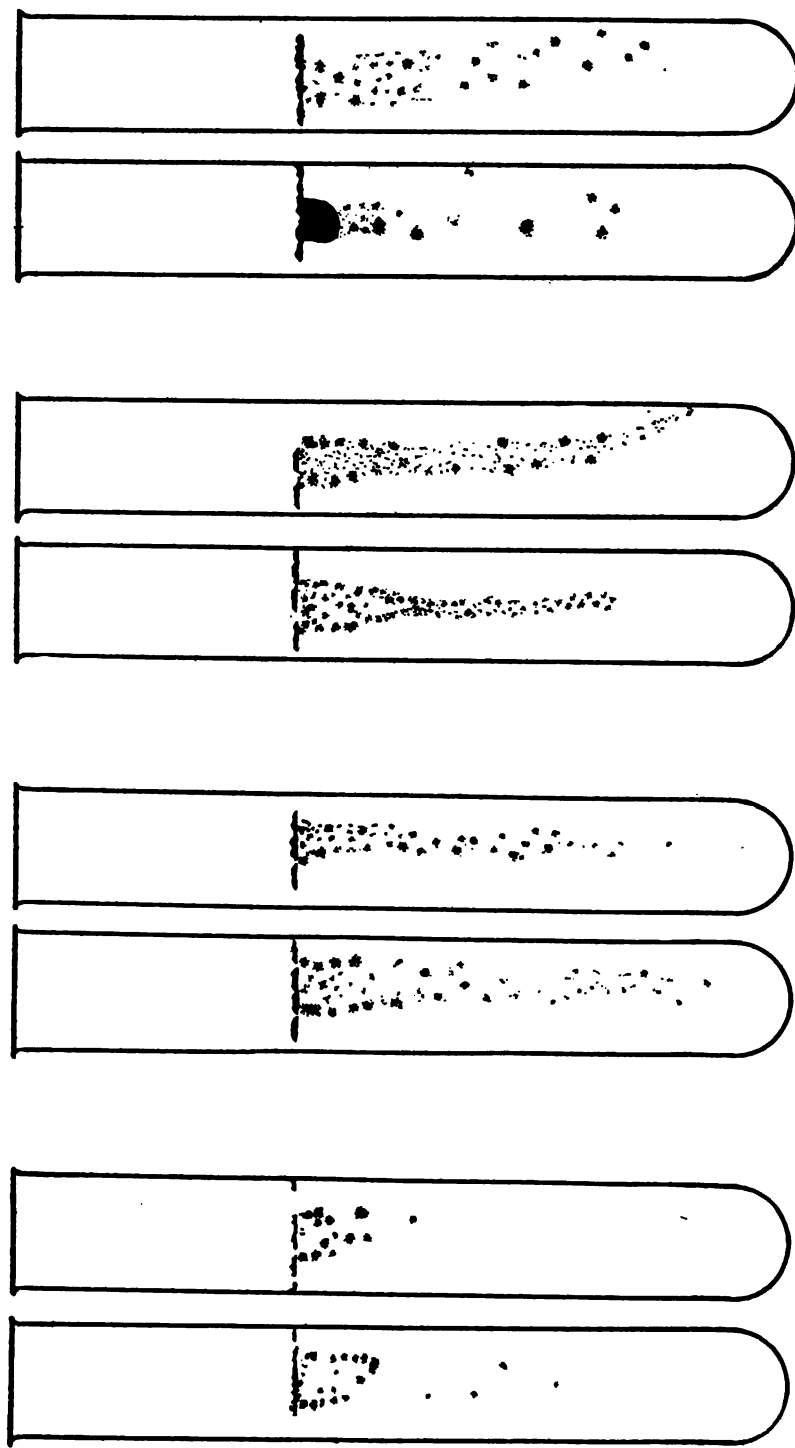


PLATE XII.—Growth of *Actinomyces chromogenus*, Nos. 1, 150, 151 and 14 in plain agar stabs, incubated at 25° C. for 10 days, showing nature of growth along the line of puncture and the elevation of surface colonies.

the cultures have been kept for several weeks. Nos. 150 and 151 produce a small quantity of cretaceous growth after 5 days.

Egg albumen: The white of six eggs is distributed among a number of test tubes, slanted and autoclaved for 10 minutes at 5 pounds pressure. These slants are not smooth, as large and irregular cavities in the medium are formed by escaping air. The growth is very slow, after 48 hours appearing as a brown smear, in 5 days spreading and becoming coriaceous, glistening and dark brown, the medium becoming a very dark brown. No further changes are noted. The organism does not develop very rapidly on this medium.

Blood serum: Blood serum slants are made by sterilizing blood serum in the autoclave at 5 pounds for 10 minutes. The growth is very slow. The medium in 24 hours becomes a dark brown but no growth is observed until after 5 to 10 days. No. 14 alone shows small, effuse, brown colonies after 5 days. Growth is indicated, however, by the browning of the medium.

Blood serum broth: The growth is slow, none appearing before 3 days. At the end of 5 days growth appears as a straw-colored ring composed of small, flocculent filamentous colonies suspended at the surface. The broth is browned and clarified to a depth of 25 to 30 mm. No. 151 gives better growth in this medium than any other strain; No. 14 gives very little growth.

The growth of these organisms is very slow on either coagulated blood serum slants or in the broth. This may have been due to the nature of this special lot of serum, or it may be that the organism does not find in blood serum a suitable medium.

Potato glucose agar strokes: 250 grams of potatoes are sliced and boiled in 500 cc. of distilled water for 30 minutes, the water filtered off and made up to 500 cc., 1% agar and 2% glucose added, the agar being dissolved by steaming, autoclaved at 10 pounds for 10 minutes, filtered, tubed and sterilized at 10 pounds pressure for 10 minutes.

The growth appears in 48 hours as punctiform, straw-colored colonies. By 72 hours the medium begins to show browning and by 96 hours the browning is quite marked, having penetrated to a depth of 5 to 6 mm. The growth generally consists of a large number of colonies ranging from barely visible or punctiform to colonies, 2 mm. in diameter, slightly raised and straw-colored. It was noted that the growth does not appear on the agar covered with the water of condensation at the bottom of the slant, possibly because of its strong

anaerobic characters. The growth continues and by 7 days may have spread or united, giving the appearance of a smear beset with papillae. Browning has materially increased, the medium being a dark brown to a depth of 8 to 10 mm., and in the course of 10 days it becomes almost black. After 16 days the growth may be described as forming a heavy, thick, coriaceous, papillate, much wrinkled coating over the whole surface. Very often the papillae crack, leaving an irregular triangular or star-shaped opening in the center of the colony. For 23 days the growth continues to increase and to become more wrinkled and contoured, resembling the inside of a chicken's gizzard, and more of the papillae burst or crack open. Between 23 and 42 days there is little or no increase in growth and practically no change in appearance. The following description may be given: Growth, slate color at top and grading into a dark straw color at the bottom, glistening and semi-translucent; growth abundant, raised, spreading, wrinkled papillate and rugose. These cultures were kept for 10 weeks without further change. See plate VII.

Cultures of Nos. 14, 150 and 151 afford an entirely different appearance on this medium. All cultures are almost identical for 4 days but after that time slight differences appear. The colonies of these organisms are larger and more irregular than those of No. 1. Cretaceous growth appears on Nos. 150 and 151 in 7 days and completely covers the growth in 23 days, while No. 14 does not become cretaceous until it is much older. Browning of the medium is decidedly more intense in the case of Nos. 150 and 151; otherwise there are only minor differences of little importance. Growth is more abundant on this medium and the browning more extensive than on any other medium, except potato peptone glucose agar. It is also more suitable as a means of bringing out the peculiar characteristics of the organism than are the more common media.

Potato peptone glucose agar: This medium is made in exactly the same manner as potato glucose agar with the exception that 1% peptone is added. After 48 hours a light straw-colored growth is apparent, accompanied by slight browning of the medium. After 72 hours growth is abundant, consisting of a rugose smear containing many papillae, possibly the foci of original colonies, accompanied by a dark brown staining of the medium. By 96 hours the medium is still more deeply stained to a depth of 10 mm. The growth continues to increase and to form a tough, thick, coriaceous layer. By 7 days the growth has increased materially, the brown staining extending into

the medium 15 to 20 mm. By 10 days the growth is still more wrinkled. After 16 days the growth may be described as abundant, thick, leathery, papillate, verrucose and of a straw-brown color. There is a peculiar pocket and apron form of growth developed, due to the shrinkage of the medium at the bottom of the slant. A thick growth develops over the whole surface and the edges adhere to the walls of the tube, the medium shrinks with age and draws away from the glass at the lower edge of the slant, and the growth now develops on this new surface forming the apron, the pocket being formed just above this. No further change is noted after 10 weeks.

Nos. 150, 151 and 14 show a different appearance on this medium after 16 days, but not more marked than on the potato glucose agar. The growth of these three organisms on this medium seems more abundant and accompanied by a more cretaceous surface than that on any other medium. Browning is also more marked, a very deep brown color being manifested but not the black-brown tinge observed in the potato glucose agar.

Potato plugs cooked: After 48 hours growth appears as an effuse, papillate smear over the entire surface of the potato, accompanied by slight discoloration. After 96 hours growth materially increases, becoming verrucose, contoured and wrinkled. The color of the growth and potato is a muddy gray but not brown. The growth continues to increase from day to day, by 20 days being very abundant, consisting of a single, tough, thick, contoured and very much wrinkled mat or lichenoid colony spreading over the entire surface, glistening and of a gray opalescent or slightly straw color. The potato is colored dark gray. No further change appeared, although the cultures were kept for over 6 weeks. Nos. 150 and 151 act much as does No. 1, except that slightly more vigorous growth and darker discoloration appears, and that after 10 days the surface is completely covered with an ashy-gray aerial growth.

Turnip plugs cooked: No growth appears within 48 hours. After 4 days, a slight growth of small, raised, opalescent colonies 1 to 2 mm. in diameter is manifested, but no browning. After 8 days, an abundant growth of crowded colonies occurs, giving the surface a wrinkled, umbonate, umbilicate and verrucose appearance. The growth is white and opaque, a few colonies in one series showing a slight tint of orange. By 20 days, the growth materially increases, still retaining, however, the appearance manifested at 8 days. The color of the organism in

mass on the turnips is very interesting and seems to vary with the different strains. No. 1 displays a rich cream hue with an outer edge of light cream; No. 151 resembles in structure and form No. 1, but manifests a greenish-gray color, the turnip sometimes browning; No. 150 is verrucose and cretaceous after 20 days, accompanied by distinct browning of the turnip. The growth of No. 14 is contoured, effuse, raised, translucent, the turnip being only slightly discolored. Turnip plugs seem to be a suitable medium for bringing out these differences in cultural characters. See plate IX.

Carrot plugs cooked: No growth occurs within 48 hours. After 96 hours, small, raised, opalescent colonies 1 to 2 mm. in diameter appear. After 8 days, abundant, verrucose colonies, raised and umbilicate, opalescent and semi-transparent, glistening and dull, are observed. By 20 days the growth is abundant, spreading, raised, contoured and wrinkled, straw-colored and opalescent, and the carrot is slightly discolored. After 8 days, colonies of No. 150 show a slightly wrinkled surface, partly covered with a gray, cretaceous growth. After 20 days, the surface is very rough and covered with cretaceous growth. No. 151 affords the most abundant growth, verrucose and contoured, with a gray, cretaceous surface around the edge of the colonies. No. 14 grows poorly on carrot, after 20 days showing only moderate or scanty growth, spreading and as individual colonies, effuse, and umbonate, sometimes distinctly raised and contoured, translucent and opalescent. The carrot is slightly discolored. These four strains show quite a difference in minor respects on this medium. Carrot plugs appear to bring out the differential characters quite markedly.

Beet plugs cooked: Very little growth appears within 48 hours, but in 96 hours the growth becomes fairly abundant, as small, raised, opalescent colonies and the beet is discolored. After 8 days, an abundant growth occurs of verrucose and very decidedly capitate colonies from 1 to 2 mm. in diameter, and the beet is markedly discolored. After 20 days, an abundance of a peculiar colonial-like spreading growth, contoured and overlapping, vissiculate to bullate, and dark straw-colored to opalescent, is observed. The growth is abundant with all four strains except No. 14, wherein it is moderate or scanty and effuse. Nos. 150 and 151 appear creamy and opaque, while No. 1 is opalescent and semi-transparent. No. 151 shows a marked umbilicated form of growth, while No. 150 displays a slight quantity of cretaceous surface. Beet plugs are also valuable in indicating cultural differences among these organisms.

Plain milk: There is only slight growth manifested and no change occurs in the milk within 4 days. By 8 days, however, the growth assumes a brownish-white ring formation, and the milk turns a brownish-cream color. By 20 days, a heavy, thick, contoured ring forms and the milk is a whitish-gray throughout, with a slight tinge of brown. In 30 days very little change occurs, with the exception of an increase in growth and a progressive discoloration of the milk until it assumes a greenish-brown color. Nos. 150 and 151 resemble No. 1 quite closely, except that growth seems more vigorous and the characteristics more pronounced in the former than in the latter. No. 14 shows wide variation from the other strains. The growth is more rapid and is accompanied by digestion of the milk within 96 hours to a depth of 3 to 5 mm., the balance of the milk becoming brownish-white. The milk is completely digested within 15 days, gradually becoming translucent, leaving a dark brown semi-transparent serum. Ring and pellicle formation is sometimes accompanied by digestion, but not in all cases.

Litmus milk: After 48 hours, the growth is indicated by an intensifying of the blue to a depth of 10 to 14 mm., indicating the production of an alkali, accompanied by slight surface growth. By 72 hours, the growth assumes a pellicle formation, accompanied by the deepening of the blue coloration which now extends much further into the milk. By 4 days, the upper 5 to 10 mm. changes to a tea-blue color, possibly a combination of the brown pigment and the litmus. The growth forms a very compact, contoured, wrinkled pellicle over the entire surface. The change in color of the milk does not extend to a depth of more than 25 mm. After 7 days, the above characters are intensified, the pellicle gradually becoming tougher and thicker. The milk shows zonation of different tints of brown-blue to the original litmus blue of the milk, the number and shades of the zones varying with the age of the culture as well as with the strain of the culture. By 16 days the milk displays partial digestion with a blue or black color by reflected light and a reddish-brown by transmitted light. The milk is never completely clear, but nevertheless the casein becomes partially dissolved. Nos. 150 and 151 are more active in discoloring the milk than is No. 1 and the pellicle formed with these strains shows a slight amount of cretaceous surface. No. 14 shows a change from an alkali to an acid reaction after 13 days. By 23 days the casein is digested and clarified to a depth of 30 mm., and the digestion is complete within 45 days with further indications of acid production. No. 151 also has shown the production of acid in one series of tests.

BIOCHEMICAL CHARACTERS

Indol production: The tests for indol are conducted in sugar-free broth made from Liebig's meat extract, inoculated with the desired organism and incubated at 25° C., and for periods of 5, 15 and 35 days. The test is made by adding 10 drops of sulphuric acid and 1 cc. of a 0.02 percent sodium nitrite solution to approximately 10 cc. of the culture. Indol is rarely and sparingly produced in sugar-free broth. The cultures were under observation for 35 days, and numerous tests made beside the regular ones at intervals of 5, 15 and 35 days. Nos. 150 and 151 and 14 never afforded indol reactions, while No. 1 gave a slight reaction after 15 days in one series.

Ammonification: Two hundred cc. of nutrient broth in 500 cc. flask were heavily inoculated with finely broken particles of the culture of the organism and incubated at 25° C. Ammonia determinations were made after periods of 14 and 30 days, using 50 cc. of the culture. 50 cc. of water and 2.5 grams of magnesium oxid. The usual chemical procedure for the determination of ammonia was carried out, controls being made with results as follows:

AMMONIA PRODUCTION IN NUTRIENT BROTH

Number and name of strain	Ammonia produced: equivalent to cc. of N/10 HCl per liter.	
	in 14 days	in 30 days
No. I	8	7
No. II	10	9
No. 150	14	16
No. 151	12	8.7
No. 14	7.5	..
Control flasks	0.5	0.6

These figures are small as compared with those yielded by most other bacteria under similar circumstances. This outcome seems counter to the general impression that organisms of the Actinomyces (*Streptothrix*) type are strong ammonia producers.

Acid production: Acid tests were made in plain nutrient broth and in broths containing dextrose, sucrose, lactose, manite and maltose, each 2 percent, and glycerine, 5 percent. Sixty cc. of the broth in 100 cc. flask were inoculated and incubated at 25° C. After periods of 5, 15 and 30 days the cultures were titrated against N/20 NaOH, using phenolphthalein as an indicator, with results as follows:

Cc. of acid produced equivalent to cc. of N/1 NaOH per liter:			
Plain broth	in 5 days	in 15 days	in 35 days
I	13.5	14.25	12.0
150	13.5	14.5	14.5
151	13.0	13.25	12.75
14	13.5	14.85	12.75
Control	13.5	12.1	....
Plain broth plus 5% glycerin			
I	10.75	...	13.3
150	10.75	...	13.5
151	10.95	...	14.25
14	13.0	10.5	14.0
Plain broth plus 2% dextrose			
I	1.20	....	17.2
150	11.5	....	14.7
151	12.0	....	...
14	16.25	17.25	18.4
Plain broth plus 2% sucrose			
I	11.5	....	15.2
150	10.9	....	12.75
151	10.6	....	13.75
14	14.0	14.5	16.4
Plain broth plus 2% maltose			
I	14.25	....	17.55
150	14.1	....	18.0
151	13.65	....	13.5
14	18.5	25.25	20.9
Plain broth plus 2% lactose			
I	12.5	....	16.65
150	12.15	....	17.85
151	11.25	....	14.75
14	16.0	15.25	18.0
Plain broth plus 2% manite			
I	10.75	....	15.25
150	10.25	....	13.1
151	10.5	....	14.5
14	14.0	14.1	...

Gas production: Fermentation tubes containing plain broth and broth with either 5 percent of glycerin or 2 percent of one of the following sugars, dextrose, sucrose, maltose, lactose or manite, received heavy inoculums of the various strains, and were incubated for 5 weeks at 25° C. and at room temperature (22.5° C.) for 5 weeks longer. Gas is not formed in any carbohydrate medium tested; neither have any characteristics been observed which would indicate that the organisms are able to produce gas under any circumstances.

Browning of the medium: Many organisms of the potato scab group have the power of producing a brown pigment which is soluble and diffuses through the medium in the vicinity of the colony. This browning is more or less marked in all strains known to produce potato scab. Other strains isolated from the soil do not produce browning of the medium, but some produce a blue stain, others a yellow, orange or red pigment, and all the stains seem to be diffusible throughout the medium. Claypole (12) divides the pigment into two groups, one brown and diffusible, the other yellow, pink, or bright orange and not diffusible. At least the pink and blue pigments of these organisms are capable of diffusing through the medium. Beijerinck (3) observed the brown coloration of culture medium in cultures of *Streptothrices*, particularly *Actinomyces chromogenus*. He supposed this pigment to be chinon and gave tests for it. Several attempts to confirm his results by applying his methods and tests have failed. We have not identified the brown pigment and the question as to its chemical nature must be through the medium."

While it is comparatively easy to show the relation of this organism to the thread bacteria, as was pointed out in 1911, it is a much more difficult problem to decide on the generic name which should be accepted for this group. The following are the generic characters recognized as characteristics of this group, whether called *Streptothrix*, *Actinomyces*, or one of the other numerous generic designations. "Cells either short or long, cylindrical, clavate, cuneate in form, which at times may show true branching, or long branched mycelial-like filaments, not surrounded by a sheath, without endospores but with the formation of conidia-like bodies, due to the segmentation of the cells. Division at right angles to the axis of the rod or filaments; cultures usually may or may not have a moldy appearance due to the development of aerial hyphae; growth may be accompanied by the production of a brown, pink to orange or blue pigment which may or may not diffuse considered as still unsettled.

The characters of the potato scab organism readily show that it belongs to this group. This is also confirmed by a parallel study of cultures of this organism and other organisms known to be members of this group which have been secured from various sources.

In determining the generic name for this group of bacteria reference has been made to the works of numerous authors. Among the more important are: Meyen, 1827; Corda, 1839; Cohn, 1875; Harz, 1877-78; Lehmann and Neumann, 1899; Migula, 1897 and 1900:

Chester, 1901; and Gasperini, Saccardo and others, 1891. Three of the more important recognized determinative manuals of bacteriology agree as to practically the same characters for this group, but accept a different generic designation. This is due to the fact that the founders of the different genera were not careful in selecting names which had not previously been used to designate other fungi. The following are the three generic names which are most commonly used in the different works on classification.

Chlamydothrix, Migula (Migula).

Streptothrix, Cohn (Chester).

Actinomyces, Meyen, Harz (Lehmann and Neumann).

Chlamydothrix: Migula does not recognize a genus to which this organism may correctly be referred, unless it be placed in the family *Chlamydobacteriaceae* and genus *Chlamydothrix* Migula. This genus is characterised by unbranched filaments surrounded by a sheath, characters which are quite sufficient to exclude this group of organisms.

Streptothrix, Cohn: Chester (11) recognizes the genus *Streptothrix* of Cohn and considers the genus *Actinomyces* of Harz to be a synonym. Cohn (14) described these organisms in 1875 and applied the generic designation *Streptothrix*, founding it on the species *Foersteri*. Cohn failed to recognize that Corda had described in 1839 two fungi belonging to and still retained in the family *Dematiaceae* to which he gave the generic name *Streptothrix* and the species names of *S. fusca* and *S. brune*. Engler and Prantl (18) as well as Saccardo (59) recognize Corda's genus and mention that there are 5 species, among them being *S. fusca*, Corda and *S. cinerea*, Morg. His plate clearly indicates that his organisms did not resemble the thread bacteria, as their reproductive bodies are conidia, borne terminally and in the axils of branches.

Since Corda's genus and species are recognized fungi of the *Dematiaceae*, it naturally follows that the application by Cohn of the same name to the thread bacteria which are closely related to the true fungi was a mistake and that Cohn's genus *Streptothrix* must be dropped.

Actinomyces: Lehmann and Neumann (44) recognize the genus *Actinomyces* of Harz (1877-78) as the correct name for this group of organisms. In 1877-78 Harz described the organism of lumpy jaw or actinomycosis and gave to it the name *Actinomyces bovis*, which it still bears. He, however, failed to note that Meyen described in 1827 an organism growing on a piece of fat meat in a pond of water which

he called *Actinomyce horkelii*. This organism of Meyen does not seem to have been recognized by others, and in all probability it was one of the numerous water molds which grow readily on animal tissue. Since the generic name *Actinomyce* as given by Meyen does not indicate anything definite and has fallen into disuse, there seems to be no reason why its application by Harz to a specific organism should not be recognized, particularly as it has already become firmly established and its priority does not seem to be questioned.

Species: The organism which causes the potato scab, at least many of the strains, resembles in practically every detail *Actinomyces chromogenus*, Gasperini (24) 1891, which, according to Lachner-Sandoval, is synonymous with *Streptothrix nigra* of Rossi-Doria (57) 1891; at least the main characters are identical, with the one exception that all strains do not produce a cretaceous surface growth with aerial conidia. The following is Chester's characterization:

STREPTOTHRIX CHROMOGENA GASPERINI

Morphology. Branched filaments, often evidently septate, composed of long and short elements. In the aerial hyphae by segmentation short coccoid gonidia. Stain by Gram's method. Grow at 20°, but best at 37° C. Aerobic.

Gelatin colonies. Round, slightly raised, brownish, but with a whitish dry chalky appearance in the centre, becoming concentric. Gelatin around the colony dark brown and slowly liquefied, leaving a chalky crust on the surface of the liquefied gelatin. Microscopically, filamentous, tangled, becoming opaque in the centre with a filamentous border.

Gelatin stab. In depth, short radiate bundle-like outgrowths after some time; on the surface like gelatin colonies, gelatin slowly liquefied beneath.

Agar stab. In depth, bristly outgrowths; on the surface, growth moist, yellowish, glistening, raised, becoming dry, warty; agar stained a deep brown.

Agar slant. Growth brownish, slightly spreading, becoming whitish, chalky.

Bouillon. On the surface, a delicate and, later, a tough membrane.

Glucose bouillon. Radiate masses at the bottom; medium, brownish.

Milk. A tough, yellowish-brown growth on the surface; medium rendered alkaline and peptonized.

Potato. Growth yellowish to yellowish-brown, becoming chalky. The medium is stained a deep brown or black. The culture has an intense moldy odor.

Habitat. Air, water, and stomach contents.

A comparison of the above characteristics with those of our organism will leave no doubt that they are one and the same thing and that the writers are justified in changing the name of *Oospora scabies* Thaxter to *Actinomyces chromogenus* Gasperini. The latter organism has been repeatedly isolated and described, although not always under this name.

Cladothrix dichotoma Cohn has a sheath according to the original description, but the cultural characters as given by Macé (46) are

identical with those of *A. chromogenus*. It is entirely possible that some of the authors who described their cultures of this species had *A. chromogenus* instead.

Krüger (41) claimed that his *Oospora nigrificans*, isolated from girdle scab of the beet, is distinct from *A. chromogenus*; but they agree fairly closely in their cultural characters and are probably nearly related.

Rullmann (58) found and described under the name of *Cladothrix odorifera* an organism that is of particular interest in the present discussion. The author, investigating the soil under two houses in which a typhoid fever epidemic had occurred, isolated an organism which, in culture, produced the peculiar earthy odor of garden soil. The polluted soil full of organic matter common around houses offered a favorable substratum for the growth of this fungus and always contained it. This organism, as afterward admitted by Rullman, is identical with *Actinomyces chromogenus*.

Beijerinck (3) found *Actinomyces chromogenus* to be one of the widest spread organisms in garden soil, where it was common at a depth of one metre. In sand it was found two metres below the surface and in alluvial mud, three metres. It was also common in river water and was especially abundant in and close to plant roots of various sorts. The parasitism of the organism was doubted by Beijerinck, but it must be pointed out that he gives no account of having tested the pathogenicity of the organism on either the potato or beet.

It must be said further that giving the organism the name *Actinomyces chromogenus* and indicating its almost universal occurrence, does not preclude the possibility that inside the species there are various strains, some of which are more strongly pathogenic on potato tubers and on beet roots than others. With some strains it may be necessary that the chemical and physical soil conditions be exactly right if the organism is to attack these plants successfully, while with others the surroundings may not need to be as favorable. Some of our cultures have been kept for 5 years and still retain their virulence, so that this character is not one that is readily lost under artificial conditions. The culture of *A. chromogenus* obtained from Kral's laboratory, while it differs in certain characteristics from the published descriptions and from our cultures of the potato scab organism, was found to produce scab in some cases.

Güssow (27) has proposed not only the name *Actinomyces scabies* for the scab organism, but that all the thread bacteria given in

Saccardo under the generic name *Streptothrix* should be called *Actinomyces*. The potato scab fungus, as is shown in this bulletin, has already been described and named by Gasperini in 1891 as *Actinomyces chromogenus*, and the changing of the generic name *Streptothrix* to *Actinomyces* has already been made by Gasperini, Lachner, Sandoval, Neukirch and others.

SPREAD OF THE ORGANISM

The utilization of scabby potatoes as seed has been supposed to be the principal means by which the scab organism finds its way into soil previously free from it. Undoubtedly scabby seed tubers offer an especially favorable chance for the infection of the succeeding crop. The organisms are present in the old scabs in the greatest abundance and are located in the exact region where the new tubers will be formed. The presence of humus or dung and of the remains of the body of the old tuber offer a favorable culture medium for the increase of the organisms in the hills. Manure is an almost unrecognized danger in the spread of the organism. Thaxter (74) has shown that it grows abundantly in an infusion of horse dung and the inference naturally follows that it will also multiply abundantly in the manure itself. *Oospora perpusilla*, a closely related species which, however, is not known to produce scab, has its natural habitat in manure.

In view of these facts two common farm practices are particularly to be decried as likely to result in a wholesale seeding of the farm with scab organisms, viz.: (1) dumping diseased and scabby potatoes on the manure heap and (2) feeding scabby tubers to farm stock. Morse (51) has shown that potato scab organisms survive the passage through the digestive tracts of the horse and cow and reinfect potato tubers with which the dung comes into contact. A mature horse and cow were fed scabby potatoes, the excrement collected, and added to sterile soil in which potatoes were planted with the following results:

SCABBING OF TUBERS DUE TO INFECTED MANURE
(Maine Exp. Sta., 1912)

	Total number of tubers	Number of tubers not scabbed	Percentage of scabbed tubers
Horse	61	45	26
Cow	91	91	0
Check	16	16	0
Horse	50	12	76
Cow	65	54	17
Check	17	17	0

Halsted (31) had already shown that the addition to the soil of scabby potatoes or of manure from animals that had been fed scabby potatoes would increase the amount of scab from three to five fold. Steaming the scabby tubers for 20 minutes did not seem to lessen materially the proportion of scab in the preceding crop. The passage of the organism through the digestive tract of a heifer seemed more seriously to affect the vitality than did the passage through that of a mature animal.

The organism seems not only to survive but to grow in the soil if the right conditions are provided. A case of such long persistence has been observed by one of the writers on a piece of land with the history of which he is familiar. A part of a field had been a wood-yard; its soil was full of organic matter but had borne no crop for over 40 years; yet potatoes planted after the old woodyard had been plowed produced so scabby a crop that it was unsalable. Other instances of this nature might be cited.

Sorauer (64) tested the ease with which scab could be conveyed to land that was free from it by planting scabby seed. The harvest was almost clean and his conclusion was that unless the soil was inclined to favor the scab very little of the disease would appear and that the means for control must be directed toward changing the soil conditions. It will be observed that no checks were planted with manure which had been sterilized or added to ordinary unsterilized soil in any of these experiments on the spread of the organism in that substance.

The fact that the present discussion does not derive its importance from a mere change in nomenclature of the scab organism must be still further emphasized. The cultural characters indicate definitely that the organism with which we are dealing in potato scab is a widespread, normal soil inhabitant, occurring in cultivated soils, probably everywhere. Fousek (19) found that of the total number of organisms occurring in a loam soil in Austria 20 to 30 percent were *Actinomyces albus* and *A. chromogenus*, that in a clay soil from 8 to 15 percent and that in a sandy soil from 7 to 10 percent were of the same sort, and, furthermore and important, that these organisms were abundant on the roots of many plants as well as on decaying plant debris. He further found them able to decompose peptone, blood, bone meal and straw, and to use cellulose as a source of carbon. In fact, they serve as one of the most rapid decomposers of organic matter in the soil and have a favorable effect upon the growth of certain plants.

Beijerinck (3) has found that they occur in great abundance on the roots of almost all sorts of plants, including oaks, beeches, hazelnuts, elms, alders and various ferns, and that they are also found in the soil near the roots.

Potato tubers grown in the station greenhouse in the spring of 1914 were badly infected with scab. The soil was a mixture of clay, sand and well rotted manure and had been in the benches all winter. During the growing period of the potatoes it was kept very moist. Soil was taken from various places in the beds, gram samples weighed out, dilutions made in 100 cc. water blanks without previous grinding and plates poured from plain agar from dilutions of 100,000 and 500,000. The *Actinomyces* colonies were large enough to count after 9 days. The following table shows the number per gram in the various soils.

BACTERIA IN ONE GRAM OF GREENHOUSE SOIL; COUNTS MADE ON AGAR PLATES AFTER 9 DAYS

Bench	Total number of organisms	Actinomyces		Actinomyces	
		albus ¹	albus, percent	chromogenus	chromo- genus, percent
I	2,170,000	30,000	1	0	0
II	2,190,000	400,000	18	425,000	19
III	2,590,000	580,000	22	650,000	25
IV	2,090,000	380,000	18	125,000	6
V	1,630,000	260,000	16	170,000	10
Averages	2,134,000	350,000	15	274,000	12

A certain market garden plot near Burlington produced a very high percentage of scabby beets in 1913. On April 27, 1914, soil samples taken from depths of 3, 6 and 9 inches were plated out as in the preceding experiment. The counts made on May 6, after 9 days incubation at room temperature, were as follows:

Total number of organisms	Actinomyces albus	Actinomyces albus, percent	Actinomyces chromogenus	Actinomyces chromogenus, percent
1,930,000	207,000	10.7	466,000	24.1

Twenty-seven percent of the organisms in the greenhouse and 35 percent of those in the garden soil were *Actinomyces* of one or the other species. It is not always easy to differentiate between *Actinomyces chromogenus* and the so-called *A. albus*. There is considerable variation even in the former in the amount of coloring matter produced, and unless the medium is stained sufficiently, so as to be

¹The *A. albus* may include other organisms and may be the same as *A. graminarium*.

readily recognizable, the colony might be counted as *A. albus*. The latter species has never produced scab with us. With approximately 274,000 units of *A. chromogenus* in every gram of the greenhouse soil under examination and approximately 466,000 in every gram from the garden soil, it would seem difficult for any potato tuber grown thereon to escape serious infection. There is always the possibility, however, that special conditions are necessary for infection and that some strains of this organism will produce scab much more readily than others. Inoculation trials with a number of strains of the chromogenus type seem to indicate clearly, however, that those forms with well marked characters, especially the ability to darken the media, will readily produce scab when brought into contact with a growing potato tuber.

Bolley's recent bulletin (7) on the deterioration of wheat caused by the attacks of fungi on the roots and stems of the plants, is of special importance in connection with these studies on scab. Some of his recommendations for the control of such soil fungi are particularly pertinent, especially that seed wheat should be disinfected and that the manure containing old wheat straw should not be applied directly to wheat land, but should either be rotted or be put on the land before growing other crops not related to wheat. The results herein reported on the scab organism would indicate that any such procedure would probably increase its numbers and virulence. Bolley expresses considerable faith in the rotation of crops in the control of corky scab, and it is undoubtedly true that the continued growth of potatoes on the same land increases the percentage of affected tubers. Clinton (13) found on a piece of land under his observation that in 1906 the amount of scabbing was below 5 percent, and probably not over 1 percent. The second year the proportion of scabby tubers had increased to 22 percent, in 1908 to 47 percent (the same potatoes in our general rotation fields this year were only about 1 percent scabby) and in 1909 to 63 percent. No statement is made as to the treatment of the field further than that half of it was manured each time and that the scabbing was worse on this part of the field than it was on the remaining half which only received nitrate of soda. The alternation of other crops, such as grass, oats or corn with potatoes, would seem to be highly desirable since the scab organism does not find that the conditions that are best for the growth of these crops are likewise best adapted to its own increase. In fact such periods may be regarded as starvation times for it, times in

which the weaker individuals die off. In garden soil that is always kept rich with humus it is doubtful if any such change of crops would naturally affect the numbers of the organism, for enough humus would always remain in the soil for it to survive in abundance until another crop of potatoes was planted. The indefinite continuation of scab in rich garden soils is a matter that can be confirmed in any part of the country, and no investigator has yet dared to put an estimate upon the length of time which it remains active.

The question of the advisability and effectiveness of the disinfection of seed tubers comes prominently to the front if the statements as to the nomenclature and widespread occurrence of the organism presented in this bulletin are correct. It is doubtful if there is any rich garden soil in which it cannot be found in abundance; indeed the characteristic earthy odor usually found in such soils is one of its products, and Rullmann (58) has made a new species of this organism, *Actinomyces odorifera*, because of this peculiar property.

At the present time it is difficult to find land in the older regions of this country, such as New England, upon which potatoes have not been grown, or into which the organism has not been transferred in some manner. There are all sorts of opportunities for the infection of soil by an organism which can be carried so easily and which lives readily there as a normal inhabitant. It is highly probable that it has always been present in rich soil and that no inoculation by human hands is necessary to introduce it. The thread bacteria of this group undoubtedly play an important role in the chemical changes which some of the ammonia compounds undergo, and in the process receive a large share of their energy. The practicability of seed potato disinfection is therefore questionable. Although it is true that experiment station bulletins without exception recommend it, a study of the work that has been done along the line of seed tuber disinfection will show that no claim for its value is made if the soil is already infected. The chemical reaction and the moisture content of the soil are of much more importance than is tuber disinfection. If the soil is quite alkaline in its reaction and is very moist, a bad crop of scabbed potatoes will almost inevitably result. Future experiments looking towards the prevention of potato scab ought, therefore, to be considered along one of two lines; viz. (1) killing the organism in the soil, or at least preventing its growth; (2) correcting soil conditions, i. e. excessive alkalinity and moisture, so that these thread bacteria will not grow as rapidly.

The writers recommend, therefore, in the disinfection of badly scabbed tubers, to use either formaldehyde or corrosive sublimate. The tubers may be soaked for two hours in a solution of a pint of the commercial formaldehyde in 30 gallons of water, or for the same length of time in a solution of one ounce of corrosive sublimate to 15 gallons of water. Of course badly infected seed tubers should not be planted if others can be had, as their germination is always somewhat inferior, but if no others are available they may be used after disinfection. The decaying mother tuber furnishes an admirable growing place for the *Actinomyces* in that portion of the soil where new tubers are to be formed. This condition of affairs is aggravated if any quantity of manure or humus is in the soil and the chemical reaction is alkaline. If scabbing of the seed tubers is only occasional and the spots are small, but little gains are to be derived from seed disinfection. Not only is the benefit slight, but there is always the chance of injuring the seed to some extent even though the operation is carefully done. Stewart and Gloyer (65) have shown that tubers disinfected by formaldehyde or strong corrosive sublimate solutions may develop sunken brown spots surrounding the lenticles and eyes. Tubers that have sprouted are especially susceptible to injury around the eyes. This would overcome the small benefit derived from this practice.

SCAB PREVENTION

Three methods of scab prevention have been recommended by various workers. These have been under observation almost constantly since the malady has been the subject of scientific investigation. They are: (1) fungicidal treatment; (2) the application of reputed retarders to the soil; (3) crop rotation. Though aiming at the same goal their methods are widely different in practice and application. Disinfection seeks to remove the organism from the seed tubers before planting; soil treatment aims at destroying the organism or rendering it inactive through the use of some deterrent soil amendment; and the supposed efficacy of crop rotation is based upon the assumption that if potatoes or other susceptible crops are not grown continuously on the same soil the organism will ultimately die out or be so diminished in numbers as to be capable of being held in check. The means by which the results were obtained were not at first fully understood, since it was contended that the disease was not caused by living organisms but by lifeless soil substances, physical or chemical in nature. Nevertheless, research led to the conclusion that certain fungicidal treat-

ments tended to reduce scab and under well controlled conditions to prevent it entirely.

During the summers of 1912 and 1913, a series of trials were conducted at Burlington with a view of studying the influence of certain materials on the scabbing of potatoes in this section of the country. It was not the intention of the writers to test any new chemical method of control, as almost every substance that might be a possible preventive has been used in experimental trials. The results obtained, at various locations, however, have not been always in agreement and it was felt that the importance of the work made a repetition desirable under Vermont conditions. The 1912 tests were made on a heavily manured, light sandy soil which had been in grass for several years but was in a good state of cultivation. The potatoes, with the exception of those planted in the drills with fresh lime and manure, were planted by a potato planter. Where manure and lime were used, the tubers were plowed in and the manure or lime scattered in on top of the seed. The 1913 tests were made on a rich, heavy clay loam which had been in potatoes in 1912 and was known to produce a scabby crop. The seed was placed in hills made with a hand hoe and the material to be tested was scattered in the hill with the seed tubers. Duplicate tests of each material were made, in the most cases using 20 hills in each series. Green Mountains were planted in 1912 and Early Rose in 1913. Both lots were disinfected in 1 ounce of formaldehyde in 2 gallons of water for 2 hours.

The mature potatoes were dug and examined. Records were made of the weights rather than of the numbers of the tubers. The total weights of unscabbed tubers, of those badly scabbed and of those slightly scabbed, will be found in the accompanying tables viii and ix on page 61.

A careful study of the yields from the various plots will make it clear that the effect of the chemicals used was not nearly as marked as those noted by other experimenters. In 1912, a slight decrease in the percentage of clean tubers resulted from the use of the slaked lime, while the increase in percentage of tubers not scabbed resulting from the use of barnyard manure and sulphur amounted to less than 10 percent and may have been due to accidental variation in the experimental plots. Even less can be said of the effects of chemicals and manure in 1913. A small increase in the percentage of clean tubers over that of the controls resulted from practically all the treatments tested. It is doubtful if these results are at all conclusive. The

work must be repeated for a number of years on a variety of soils before it will be safe to recommend any of these treatments for general practical work. It should be pointed out, however, that the results might have been different if trials were conducted for a long and unbroken series of years on the same plot. At the present time the only thing that can be said of the results is that no chemical applied for a single season seems under the conditions obtaining during the trials to exert any marked effect on the scab organism in the soil.

SUMMARY OF OUR KNOWLEDGE ON THE EFFECT OF CERTAIN SOIL
TREATMENTS ON POTATO SCAB

Since, as has been pointed out, experiments and observations strongly indicate that certain chemicals and fertilizers influence to a marked degree the extent of potato scabbing, it seems advisable to collate these observations and to summarize not only the results above cited but also the work of others. Among the more important and more commonly used materials are: barnyard manure, lime, ashes, sulphur, potash salts, nitrate of soda and bone meal. The most extensive investigations in the matter of scab prevention in this country have been made by Halsted (28, 29, 30, 31, 32) at the New Jersey Station. In this connection attention is called to the tables which set forth the results attained in many sections and under varied conditions.

The tabulations display among other information the test conditions (kind of soil, previous usage, and fertilizer usage other than of the specific substances tested). The first column of figures shows the percent of tubers scabbed in the test rows; the second, the percent of tubers scabbed in the check rows; and the third, the percentage differences. The plus sign indicates increased scabbing following treatment and the minus sign indicates reduced scabbing following treatment.

Barnyard manure undoubtedly favors scabbing, as indicated herein (page 55) in trials by Beckwith (2), Kinney (39), Halsted (28), Lamson (43), Sturgis (69) and others. The extent of scabbing in soil rich in humus depends somewhat on other conditions, such as moisture, etc. Beckwith has shown that barnyard manure used in relatively dry soils increased scabbing by 9 percent, whereas under conditions similar save that irrigation was practiced, the scabbing was increased 49 percent. This was undoubtedly due to the more rapid decomposition of the manure induced by the increased soil water content. As has already been indicated Morse and Halsted have shown that barnyard manure from animals fed on scabby potatoes is liable to

contain the scab organism, and Thaxter points out that the organism grows readily or luxuriantly in a water extract from horse dung.

The reason for this increase when manure is used is difficult to explain, since its mode of action is not clearly understood. Furthermore the same type of action does not invariably follow its use. To the alkaline reaction of lime, ashes, marl, etc., is usually attributed their scab-producing tendencies, but manure is generally supposed to increase soil acidity, which theoretically should reduce the tendency towards scabbing. It would seem as if its ill effect may be due to the mechanical and physiological action of manure. It improves a soil's tilth, aeration and water-holding powers and augments the organic matter content and affords conditions most favorable to the development of the scab organism. See table i, page 55.

Lime has long been known to aggravate scabbing. Indeed many early observers supposed that its chemical effects on the potato produced the trouble. Beckwith (2), Halsted (28), Wheeler (76), Lamson (43) and others have studied this question. A few cases are recorded wherein liming showed a tendency to reduce scabbing or to have been inactive, but usually the reverse has been true, sometimes as high as 40 percent increase or more being noted. Liming is deemed a preventive of some soil and plant ills, but it should not be used on potatoes. Its malign influence is doubtless due to its action on the soil. It tends to promote porosity, to increase water-holding powers, to liberate other plant nutrients and to neutralize soil acidity. This latter effect is important since the organism best develops in an alkaline or very slightly acid habitat. See table ii, page 56.

Ashes. Wood ashes have repeatedly increased scabbing, and are listed among the early writings as causing or aggravating the malady. Halsted, however, failed to indicate such an effect. On the other hand Wheeler (77) and Lamson (43) show a decided increase in scab when they were applied. Beckwith (2) found that coal ashes reduced scabbing as much as 26 percent.

Since ashes (other than coal ashes) are alkaline, one would expect them to increase scabbing; but they also contain some potash, which in some combinations tends to decrease scabbing. In other words, some of their constituents may and others may not aggravate scab. See table iii, page 57.

Potash salts. Kainit is a natural Stassfurt salt carrying 20 percent of potash which is used extensively in fertilization. It almost invariably reduces or tends to control the ravages of potato scab.

Halsted (28) carried on extensive experiments on badly infected soil. In one series there was from 37 to 42 percent less scabbing where kainit was used than where it had not been applied. However, he found that when used at the rate of 1500 pounds or more per acre it injured the crop, and, furthermore, that soaking the seed in a kainit solution proved as effective as did its free use as a fertilizer.

The manufactured Stassfurt salts, muriate and sulphate of potash, seem almost invariably to reduce scabbing. Beckwith (2) and Taft (72) show material gains in this respect by their use in the potato hills. Whether these results were due to the potash contents of these salts or not is not clear, but this appeared to be the one common factor. See table iv, page 58.

Bone meal. No extensive trials have been made with bone meal, yet Beckwith (2) believes that scabbing is increased by its use. Bone meal may be taken as a form of phosphatic fertilizer and this, taken with the figures of Lamson which show that "phosphate" increased scab, may indicate that phosphatic fertilizers favor potato scabbing. See table v, page 58.

Sulphur may be considered at least as a partial preventive, although this statement is not universally accepted. Beckwith (2), Halsted (28), and Sturgis (67) show an invariable reduction of scab following its use at the rate of 150 or 300 pounds per acre, or where moist seed tubers were rolled therein, the benefit varying from 7 to 46 percent and in one case as high as 95 percent. On the other hand trials by Brooks (8), Garman (23) and Taft (72) indicate that sulphur is ineffective or worse. The great majority of experiments recorded indicate that under most conditions sulphur, used at the rate of 300 pounds per acre or as a coating to seed tubers, tends to reduce scab ravages. Doubling this dosage according to Halsted (28) did not materially lessen the scab, increased the cost and slightly injured the crop. The value of sulphur no doubt lies in its fungicidal nature, as several sulphur derivatives may form in the soil, such as sulphuric and sulphurous acids. See table vi, page 59.

Wheeler (78) has shown that sulphur applied to acid soils or to those poor in basic materials, may be injurious to succeeding crops. He believes that sulphate of ammonia may be applied advantageously as a scab preventive without injuring succeeding crops.

Miscellaneous materials. Numerous other materials have been tested by various workers, some of which were found to encourage scabbing while others seemed to retard it. Among those substances

which have reduced scabbing are, hyposulphite of soda, common salt, and corrosive sublimate; among those which increased it are, nitrate of soda, wheat bran, and sawdust. See table vii, page 60.

The results obtained by Stone and Chapman (71) with a variety of chemicals seem inconclusive, but sulphur and a commercial by-product called "by-product A" produced some favorable results.

POTATOES RESISTANT TO SCABBING

The growth of immune or disease resistant plants, if such can be developed, is to be preferred to recourse to various treatments of ordinary non-resistant sorts, which even at the best afford only temporary relief. Just what it is that renders a plant disease resistant is not always clear. It may be dependent upon the physiological nature of the host plant and to some extent, undoubtedly, depends on its morphological structure. Unfavorable surroundings may cause it to become more susceptible to disease by lowering its vitality and impairing its health. Morphological factors are obviously easier to deal with than are the physiological factors. Potato scab is a disease of the cork and outermost layers of the starch parenchyma. Naturally, therefore, these structures as they occur on different varieties of potatoes have been studied with reference to their relation to potato scab. The color of the skin, whether dark, light or pink and white, and its thickness have been compared with the susceptibility to scab of divers varieties. The range of variation of the disease resistance of the sorts tested seem somewhat wide; but this phase of the matter needs no discussion here as no work has been done by the writers, but reference in this connection should be made to the extensive series of statements as to diseases resistance of potatoes to scab, on pages 159-165 in bulletin 179 of this Station. Beckwith (2), Humphrey (38), Kinney (39), Rane and Hunt (56), Halsted (33), Craig (16), Williams (79), Sheppard and Ten Eyck (61), Norton (54) and Stuart (66) may be mentioned among those who have published data. The virulence of the organism is so dependent on the chemical and physical conditions of the material in which the tubers are grown, that any series of varieties comparatively studied as to their disease resistance to scab must be grown under widely diverse soil and climatic conditions before the results can be accepted as conclusive. Isolated tests, such as have just been cited, if properly conducted, contribute to our knowledge; but much more confirmatory evidence must be secured before one will be justified in vaunting any particular variety as disease resistant.

TABLE 1—EFFECT ON SCABBING OF USE OF BARNYARD MANURE

Author	Station and date	Soil, climatic conditions, etc.	Details as to special treatment	Percentage scabbed tubers on trial area	Percentage scabbed tubers on check area	Percentage increase or decrease in scabbing: total crop = 100
Beckwith	N. Y.	'87 Garden, irrigated, dry season.....	Before plowing	71.	22.	+49.
Beckwith	N. Y.	'87 Garden, dry season	Before plowing	30.	21.	+9.
Kinney	R. I.	'91 Loam, natural drainage, grass, rich.....	Underneath	26.4	13.7	+12.7
Kinney	R. I.	'91 Loam, natural drainage, grass, rich.....	Above	44.5	13.7	+20.8
Halsted	N. J.	'95 Previous year's crop badly scabbed.....	"Full amount"	85.	47.	+38.
Halsted	N. J.	'95 Previous year's crop badly scabbed.....	"Half amount"	50.	47.	+3.
Halsted	N. J.	'95 Previous year's crop badly scabbed.....	"Quarter amount"	75.	47.	+28.
Halsted	N. J.	'95 Previous year's crop badly scabbed.....	Scattered in hill	55.	47.	+8.
Lamson	N. H.	'97 Commercial fertilizer on control.....	Quantity not given	14.	37.	-23.
Lamson	N. H.	'98 No potatoes for years; seed disinfected.....	Quantity not given	20.	5.	+15.
Lamson	N. H.	'98 No potatoes for years	Quantity not given	40.	19.	+21.
Sturgis	Conn.	'96 Not recently in potatoes; soil supposedly scab free	Fresh	73.	50.	+23.
Sturgis	Conn.	'96 Not recently in potatoes; soil supposedly scab free	Composted (old)	60.	50.	+10.
Sturgis	Conn.	'96 Not recently in potatoes; soil supposedly scab free	Fresh	74.	40.	+34.
Sturgis	Conn.	'96 Not recently in potatoes; soil supposedly scab free	Composted (old)	68.	40.	+28.

(a) Dug early, Sept. 14. (b) Dug late, Oct. 20.

TABLE II—EFFECT ON SCABBING OF USE OF LIME

Author	Station and date	Soil, climatic conditions, etc.	Details as to special treatment	Percentage scabbed tubers on trial area	Percentage scabbed tubers on check area	Percentage increase or decrease in scabbing: total crop = 100
Beckwith	N. Y.	'88 Garden, manured; check unmanured.....	Air slaked; tablespoonful per hill	89.	47.	+42.
Halsted	N. J.	'95 Previous year's crop very scabby.....	Slaked; 300 bu. per acre.....	85.	47.	+38. (a)
Halsted	N. J.	'95 Previous year's crop very scabby.....	Slaked; 150 bu. per acre.....	15.	47.	-32. (b)
Halsted	N. J.	'95 Previous year's crop very scabby.....	Slaked; 75 bu. per acre.....	90.	47.	+43.
Halsted	N. J.	'95 Previous year's crop very scabby.....	Slaked; potatoes rolled in....	50.	47.	+3.
Wheeler <i>et al.</i>	R. I.	'95 Pot trials; full plant food ration used.....	Air slaked; 2½ tons per acre..	98.4	23.5	+74.9
Lamson	N. H.	'98 Not recently in potatoes.....	Air slaked	11.	10.	+1.
Lamson	N. H.	'98 Not recently in potatoes.....	Air slaked	53.	27.	+26.
Lamson	N. H.	'98 Not recently in potatoes.....	Air slaked	0.	5.	-6.
Lamson	N. H.	'98 Not recently in potatoes.....	Air slaked	42.	19.	+23.
Wheeler <i>et al.</i>	R. I.	'93 Sandy loam, gravelly subsoil.....	Air slaked	47.7	15.7	+32.
Wheeler <i>et al.</i>	R. I.	'93 Sandy loam, gravelly subsoil.....	Air slaked; 5,400 lbs. per acre.	48.5	3.3	+45.2

(a) Crop injured; only 75% stand. (b) Crop injured; only 80% stand.

TABLE III—EFFECT ON SCABBING OF USE OF ASHES

Author	Station and date	Soil, climatic conditions, etc.	Details as to special treatment	Percentage scabbed tubers on trial area	Percentage scabbed tubers on check area	Percentage increase or decrease in scabbing: total crop = 100
Beckwith	N. Y. '88	Garden, in field	Coal ashes, handful per hill...	18.	44.	—26.
Halsted	N. J. '95	Cabbages; ashes used in '94	Wood, ashes, 300 bu. per acre, '94	100.	100.	0.
Halsted	N. J. '95	Cabbages; ashes used in '94	Wood ashes, 150 bu. per acre, '94	100.	100.	0.
Halsted	N. J. '95	Cabbages; ashes used in '94	Wood ashes, 75 bu. per acre, '94	100.	100.	0.
Wheeler <i>et al.</i>	R. I. '95	Pot trials; full plant food ration used	Wood ashes; calcium equi. ½ ton per acre	100.	23.5	+76.5
Lamson	N. H. '98	Not recently in potatoes; seed disinfected	Wood ashes	30.	10.	+20.
Lamson	N. H. '98	Not recently in potatoes; seed not disinfected	Wood ashes	66.	27.	+39.
Lamson	N. H. '98	Not recently in potatoes; seed disinfected	Wood ashes	5.	5.	0.
Lamson	N. H. '98	Not recently in potatoes; seed not disinfected	Wood ashes	72.	19.	+53.

TABLE IV—EFFECT ON SCABBING OF USE OF POTASH SALTS

Author	Station and date	Soil, climatic conditions, etc.	Details as to special treatment	Percentage scabbed tubers on trial area	Percentage scabbed tubers on check area	Percentage increase or decrease in scabbing: total crop = 100
Beckwith	N. Y.	'87 Garden, manured, irrigated, dry season.....	Muriate, $\frac{1}{2}$ oz. per hill.....	80.	84.	- 4.
Beckwith	N. Y.	'87 Garden, irrigated, dry season.....	Sulphate, $\frac{1}{2}$ oz. per hill.....	63.	84.	-21.
Beckwith	N. Y.	'87 Garden, manured, dry season.....	Muriate, $\frac{1}{2}$ oz. per hill.....	20.	47.	-27.
Beckwith	N. Y.	'87 Garden, manured, dry season.....	Sulphate, $\frac{1}{2}$ oz. per hill.....	25.	47.	-22.
Beckwith	N. Y.	'87 Garden.....	Sulphate, $\frac{1}{2}$ oz. per hill.....	43.	44.	- 1.
Taft	Mich.	'90 Sandy, well decomposed muck, loose.....	Sulphate, 2 lbs. per $1\frac{1}{2}$ rods..	47.	53.	- 6.
Haisted	N. J.	'95 Previous year's crop badly scabbed.....	Sulphate, 2 lbs. per $1\frac{1}{2}$ rods..	93.4	100.	- 6.6
Haisted	N. J.	'95 Previous year's crop badly scabbed.....	Kainit, 3,000 lbs. per acre....	8.	47.	-39. (a)
Haisted	N. J.	'95 Previous year's crop badly scabbed.....	Kainit, 1,500 lbs. per acre....	5.	47.	-42. (b)
Haisted	N. J.	'95 Previous year's crop badly scabbed.....	Kainit, 750 lbs. per acre....	10.	47.	-37.
Haisted	N. J.	'95 Previous year's crop badly scabbed.....	Kainit, seed soaked in.....	5.	47.	-42.
Haisted	N. J.	'95 Previous year's cabbage badly clubbed.....	Kainit, 2,000 lbs. per acre....	100.	100.	0.
Haisted	N. J.	'95 Previous year's cabbage badly clubbed.....	Kainit, 1,000 lbs. per acre....	100.	100.	0.
Haisted	N. J.	'95 Previous year's cabbage badly clubbed.....	Kainit, 500 lbs. per acre.....	100.	100.	0.

(a) Crop injured; only 25% of normal stand. (b) Crop injured; only 50% of normal stand.

TABLE V—EFFECT ON SCABBING OF USE OF BONE MEAL

Beckwith	N. Y.	'87 Garden, manured, irrigated, dry season.....	Tablespspoonful per hill.....	85.	84.	+ 1.
Beckwith	N. Y.	'87 Garden, manured, dry season.....	Tablespspoonful per hill.....	86.	47.	+39.
Beckwith	N. Y.	'88 Garden.....	Handful per hill.....	56.	44.	+12.
Beckwith	N. Y.	'88 Garden.....	$\frac{1}{4}$ handful per hill.....	49.	44.	+
Taft	Mich.	'90 Sandy and mucky, loose and open.....	4 lbs. per $1\frac{1}{2}$ rods.....	53.	53.	0. (a)
Taft	Mich.	'90 Sandy and mucky, loose and open.....	4 lbs. per $1\frac{1}{2}$ rods.....	100.	100.	0. (a)

(a) Two pounds sulphate of potash per row.

TABLE VI—EFFECT ON SCABBING OF USE OF SULPHUR

Author	Station and date	Soil, climatic conditions, etc.	Details as to special treatment	Percentage scabbed tubers on trial areas	Percentage scabbed tubers on check areas	Percentage decrease in scabbing: total crop = 100
Beckwith	N. Y.	'88 Garden soil, in field	Cuttings moistened and rolled	18.	44.	-26.
Beckwith	N. Y.	'87 Garden soil, manured	Tablespoonful per hill.....	56.	84.	-28.
Beckwith	N. Y.	'89 Garden soil, manured	Tablespoonful per hill.....	19.	47.	-28.
Taft	Mich.	'90 Sand and muck, loose	7½ ozs. per 1½ rods.....	64.	53.	+11.
Halsted	N. J.	'95 ".....	7½ ozs. per 1½ rods.....	95.	100.	-5.
Halsted	N. J.	'95 Previous year's crop very scabby.....	600 lbs. per acre	5.	47.	-42. (a)
Halsted	N. J.	'95 Previous year's crop very scabby.....	300 lbs. per acre	1.	47.	-46.
Halsted	N. J.	'95 Previous year's crop very scabby.....	150 lbs. per acre.....	1.	47.	-46.
Halsted	N. J.	'95 ".....	Potatoes rolled in	5.	47.	-42.
Garman	Ky.	'95 Cabbages, previous year.....	300 lbs. per acre	5.	100.	-95.
Chester	Del.	'98 Known to be scab infected.....	".....	52.2	42.9	+ 9.3 (b)
Chester	Del.	'98 ".....	300 lbs. per acre.....	12.4	26.8	-14.4
Brooks	Mass.	'97 Badly infected, seed corrosive subl. treated.....	Seed rolled in.....	10.2	20.3	-10.1
Brooks	Mass.	'97 Badly infected.....	300 lbs. per acre, in rows.....	13.5	1.4	+12.1
Sturgis	Conn.	'98 Previous crop, 75% scabbed; clean seed.....	300 lbs. per acre.....	100.	100.	0.
Sturgis	Conn.	'96 Previous crop, 75% scabbed; scabby seed.....	Seed rolled in	36.	56.	-21. (c)
Sturgis	Conn.	'96 Previous crop, 75% scabbed; scabby seed.....	Seed rolled in	36.	74.	-38. (c)
Sturgis	Conn.	'96 Previous crop, 75% scabbed; scabby seed.....	Seed rolled in	25.	32.	-7. (d)
Sturgis	Conn.	'96 Not recently in potatoes, supposedly scab free.....	Seed rolled in	45.	54.	-9. (d)
Sturgis	Conn.	'96 Not recently in potatoes, supposedly scab free.....	Seed rolled in 230 lbs. per acre.....	19.	50.	-31. (c)
Sturgis	Conn.	'96 In potatoes '96, '97, '98; 240 lbs. sulphur in '96.....	Seed rolled in 230 lbs. per acre.....	23.	40.	-17. (d)
Halsted	N. J.	'98 In potatoes '96, '97, '98; 480 lbs. sulphur in '96.....	480 lbs. per acre	10.	60.	-50. (e)
Halsted	N. J.	'98 In potatoes '96, '97, '98; 480 lbs. sulphur in '96.....	360 lbs. per acre	15.	60.	-45. (e)
Halsted	N. J.	'98 In potatoes '96, '97, '98; 120 lbs. formalin in '97.....	720 lbs. per acre	15.	60.	-45. (e)
Halsted	N. J.	'98 In potatoes '96, '97, '98; 360 lbs. formalin in '96.....	720 lbs. per acre	10.	60.	-50. (e)
Jones, Edison	Vt.	'04 Light sandy loam, mostly never cultivated.....	500 lbs. per acre	7.	22.	-15.
Stone, Chapman	Mass.	'13 23 inch tiles used	50 grams per tile	70.	85.	-15.
Stone, Chapman	Mass.	'13 23 inch tiles used	200 grams per tile.....	60.	85.	-25.

(a) Vitality slightly injured. (b) Average 5 tests. (c) Dug early, Sept. 4. (d) Dug late, Oct. 20. (e) Control received 120 lbs. benzene.

TABLE VII—EFFECT ON SCABBING OF USE OF MISCELLANEOUS MATERIALS

Author	Station and date	Soil, climatic conditions, etc.	Details as to special treatment	Percentage scabbed tubers on trial area	Percentage scabbed tubers on check area	Percentage increase or decrease in scabbing: total crop = 100
Beckwith	N. Y. '88	Garden soil	Nitrate of soda $\frac{1}{2}$ oz. per hill	48.	44.	+ 4.
Beckwith	N. Y. '88	Garden soil	Bran, handful per hill	61.	44.	+17.
Beckwith	N. Y. '88	Garden soil	Sawdust, handful per hill	60.	44.	+16.
Beckwith	N. Y. '88	Garden soil	Common salt	33.	44.	-11.
Halsted	N. J. '95	Well tilled, previous year's crop scabby	Corrosive sublimate, 120 lbs. per acre	5.	47.	-42.
Halsted	N. J. '95	Well tilled, previous year's crop scabby	Corrosive sublimate, 60 lbs. per acre	5.	47.	-42.
Halsted	N. J. '95	Well tilled, previous year's crop scabby	Corrosive sublimate, 30 lbs. per acre	2.	47.	-45.
Halsted	N. J. '95	Well tilled, previous year's crop scabby	Corrosive sublimate, seed soaked in	1.	47.	-46.
Halsted	N. J. '95	Previous cabbage crop, badly clubbed	Corrosive sublimate, 30 gals. of 1:1000 sol. per acre	88.	97.	- 9.
Halsted	N. J. '95	Previous cabbage crop, badly clubbed	Gas lime, 150 bus. per acre	100.	100.	0.
Halsted	N. J. '95	Previous cabbage crop, badly clubbed	Gas lime, 75 bus. per acre	100.	100.	0.
Halsted	N. J. '95	Previous cabbage crop, badly clubbed	Gas lime, 37½ bus. per acre	...	100.	0.
Taft	Mich.	Sandy, loose soil, well decomposed muck	Hyposulphite of soda, 12 ozs. per 1½ rods	77.	100.	-33.
Halsted	N. J. '95	Well tilled, previous year's crop scabby	Copper sulphate, 300 lbs. per acre	5.	47.	-42.
Halsted	N. J. '95	Well tilled, previous year's crop scabby	Copper sulphate, 150 lbs. per acre	5.	47.	-42.
Halsted	N. J. '95	Well tilled, previous year's crop scabby	Copper sulphate, 75 lbs. per acre	2.	47.	-45.
Halsted	N. J. '95	Well tilled, previous year's crop scabby	Seed soaked in copper sul- phate sol.	1.	47.	-46.

TABLES VIII AND IX—EFFECT ON SCABBING OF USE OF SUNDRY FERTILIZERS, ETC., AT VERMONT STATION. VIII, 1912; IX, 1913

Treatment	Weight of potatoes in pounds				Percentage			Percentage increase or decrease in scabbing
	Total	Not scabbed	Badly scabbed	Slightly scabbed	Not scabbed	Badly scabbed	Slightly scabbed	
VIII, 1912								
Barnyard manure, a heavy application scattered in the rows	27.0	24	0.5	2.5	88.9	1.8	9.3	— 8.9
	26.0	22	3.0	1.0	84.6	11.5	3.9	— 4.6
Fresh unslaked lime, a heavy application scattered in the rows	25.5	21	4.5	0.0	82.3	17.7	0.0	— 2.3
	32.0	18	8.0	6.0	56.3	25.0	18.7	+23.7
Slaked lime, scattered in the rows	25.0	10	10.0	5.0	40.0	40.0	20.0	+40.0
	29.0	20	3.0	6.0	69.0	10.3	20.7	+11.0
Sulphur, 300 pounds per acre scattered in the rows	25.5	22	1.0	2.5	86.3	3.9	9.8	— 6.3
	23.0	20	0.0	3.0	86.9	0.0	13.1	— 6.9
Mixed fertilizer, per acre scattered in the rows	25.5	19	4.0	2.5	74.5	15.7	9.8	+ 5.5
	23.0	20	3.0	0.0	86.9	13.1	0.0	— 6.9
Controls	22.5	18	2.0	2.5	80.0	8.9	11.1	
	20.0	16	0.0	4.0	80.0	0.0	20.0	
IX, 1913								
Lime, 150 bushels per acre	26.6	5.6	3.0	18.0	21.0	67.7	11.3	+ 6.7
	34.3	12.8	0.8	20.7	37.3	60.3	2.4	— 9.6
Common salt 300 pounds per acre	21.4	8.6	1.0	15.8	33.7	62.2	3.9	— 6.0
	27.7	6.1	0.0	21.6	22.0	78.0	0.0	+ 5.7
Potato phosphate (mixed fertilizer) 2 tons per acre	14.5	5.2	0.0	9.3	35.9	64.1	0.0	— 8.2
	16.7	9.8	0.0	6.9	58.7	41.3	0.0	—31.0
Mixed fertilizer, 2 tons per acre	12.3	3.1	0.3	8.9	25.2	72.4	2.4	+ 2.5
	3.3	2.6	0.4	0.3	78.8	9.1	2.1	—51.1
Bone meal, 1½ tons per acre	31.2	12.3	2.4	16.5	39.4	52.9	7.7	—11.7
	34.2	9.0	1.2	24.0	26.3	70.2	3.5	+ 1.4
Potassium nitrate, 600 pounds per acre	15.0	5.8	0.8	8.4	38.7	56.0	5.2	—11.0
	21.3	9.1	0.1	12.1	42.7	56.9	0.4	—15.0
Sulphur, flowers of, 600 pounds per acre	31.7	12.3	1.2	18.2	38.8	57.4	3.8	—11.1
	36.5	8.5	0.0	28.0	23.3	76.7	0.0	+ 3.4
Copper sulphate, 600 pounds per acre	29.2	15.0	3.4	10.8	51.4	56.9	11.7	—23.4
	27.5	6.1	0.0	21.4	22.2	77.8	0.0	+ 5.5
Copper sulphate, 600 pounds, and lime, 100 bushels per acre	27.5	12.5	1.8	13.2	45.4	48.0	6.6	—17.7
	27.4	11.3	0.3	15.8	41.2	57.7	1.1	—13.5
Potato phosphate, 2 tons and lime, 100 bushels per acre	23.0	11.0	0.0	12.0	47.8	52.2	0.0	—20.1
	15.7	7.8	0.0	7.9	49.7	50.3	0.0	—22.0
Potassium nitrate, 600 pounds lime, 100 bushels per acre	22.4	9.2	0.0	13.2	41.1	58.9	0.0	—13.4
	5.8	3.6	0.0	2.2	62.1	37.9	0.0	34.4
Barnyard manure, a heavy application	20.8	7.3	1.4	12.1	35.1	58.2	6.7	7.4
	24.9	8.4	0.0	16.5	33.7	66.3	0.0	6.0
Controls	33.1	9.1	0.8	23.2	27.5	70.1	2.4	
	31.5	8.8	0.9	21.8	27.9	69.2	2.9	

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Studies of Club-Root

II. Disease Resistance of Crucifers: Methods of
Combating Club-Root

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STUDIES OF CLUB-ROOT

II. DISEASE RESISTANCE OF CRUCIFERS; METHODS OF COMBATTING CLUB-ROOT

BY G. C. CUNNINGHAM

Club-root is a disease which attacks the roots of cruciferous plants, such as cabbages, turnips, radishes and related species. Woronin²⁴ and others have shown that the disease is caused by a slime mold, *Plasmodiophora brassicae*. The roots infected by the parasite become distorted and swollen to many times their normal size because of the presence of the infecting fungus within their tissues. The roots thus distorted fail to absorb nourishment from the soil and are often unable to transfer the plant food and water collected by the healthy roots to the cabbage head or other storage place. The plant starves, little or nothing being stored either in a head, as in the case of cabbage and such plant, or in a succulent tap-root as in the case of turnips and radishes.

This functional failure of the root stunts the plant. The outer and older leaves become yellow and sickly, soon drop and, in the case of cabbage and cauliflower, the head is always small. At first they wilt only in the hottest weather or during mid-day and recover in the cool of the day, appearing perfectly normal the next morning; but as the disease advances the outer leaves wither and fall one after the other until, in severe attacks, the whole plant dies, a result noticeable in July or August but most severe in September. This effect is termed "flagging."

This disease is known by many characteristic or descriptive names. It is commonly and aptly called "club-root" here, in England it is known as "Finger and Toe" and "Anbury," in Germany as "Kohlhernie." and in France as "Maladie Digitore"; names suggested by the characteristically large irregular fusiform swelling of the roots and rootlets. (See plate I).

The injury to cabbage and similar crops caused by this disease can only be appreciated by those who have seen it destroy whole crops. Cabbage, cauliflower and radish suffer most here, but in Europe, where stock turnips or rutabagas are largely raised, these crops suffer severely. Certain Scottish lands were long ago abandoned for raising turnips because of its prevalence and many American gardeners no longer raise cabbages for the same reason.

NOTE.—The author wishes to thank the station plant pathologist for valuable suggestions, Mr. H. S. Merrihew for the use of land and for hearty cooperation in the work, Prof. E. J. Howitt, of the Ontario Agricultural College, Prof. Wm. Loch-head, of the Macdonald Agricultural College, Dr. H. T. Güssow, Dominion Experimental Farms, and Mr. Peter Bisset, of the Bureau of Plant Industry, United States Department of Agriculture, for seeds of cruciferous plants.

CAUSE

The earlier investigators believed that insects and nematode worms were at fault, and undoubtedly a similar disease of nematode origin has often been confused therewith. The writer owns a turnip specimen which at first sight seems a victim of *Plasmodiophora brassicae*, which, on closer observation, appears affected by galls attached to the side of the rootlet rather than occupying its tissues (see plate VII). Bird³ and other writers, held that soil and climatic conditions were responsible and that various fertilizers encouraged clubbing, especially those tending to induce soil acidity, while others, such as lime, marl, ashes, etc. which induce alkalinity, were thought to reduce clubbing.

Woronin²⁴ was the first to make known its true cause. After three years of study he published his classical description of the disease and its cause, a microscopic organism far down in the scale of life, to which he gave the name *Plasmodiophora brassicae*. Though called a slime mold it shows no resemblance to the common thread-like mold. It seems almost equally related to plant and to animal life. De Bary⁸ placed it among the fungi, others among the protozoa. The Encyclopedia Britannica (1911) lists it among the animals. The question is quite unsettled and for the purposes of the present bulletin is unimportant.

During its vegetative or growing stage, it is a naked mass of protoplasm without definite shape or size, filling or only partially filling the host cell. Later this plasmodium, as it is called, breaks up into numerous small, almost spherical spores which become freed in the soil when the diseased root decomposes. A single root thus liberates many millions of spores capable of infecting succeeding crops. No true sporangia form and this slime mold represents a more simply organized species in consequence of its parasitic mode of life. Eycleshymer,⁹ Nawaschin,¹⁶ Prowazek¹⁷ and Lutman¹⁸ have also furnished detailed descriptions of the organism.

Galls—other than those caused by *Plasmodiophora brassicae*—are occasionally seen which at first sight might be confused with club-root. They occur on plants other than, as well as on, the crucifers. The nematode worms, *Heterodera radicola*, are especially concerned. The galls thus induced so closely resemble club-root that various authors have mistaken them for it. Thus, for example, Marchand¹⁴ described a disease of certain *Cucurbitaceae*, *Umbelliferae* and *Polygonaceae* which he claimed was caused by *Plasmodiophora brassicae* but which

Gregnan¹⁰ subsequently showed was due to nematodes. Plate VII shows a turnip thus badly infected. The swellings or galls closely resemble club-root but are really warty outgrowths on the side of the roots and rootlets and not fusiform swellings of the whole root. Crown galls may at times be mistaken for club-root, but Smith,²⁰ Townsend²³ and von Schrenk²² have clearly shown that they are distinct therefrom and due to bacterial infection.

Club-root of cabbages and other crucifers has been continuously and extensively studied by various European and American workers for scores of years. Most of these studies have been directed toward methods of prevention. They have sought to free the soil from the malady or to inhibit its spread by the use of chemicals or fertilizers. Yet it is still abundant and spreading widely, not because preventives are unknown but largely because gardeners are heedless. They are apt not only to fail to correct soil acidity by liming, an excellent preventive, but recklessly to spread the disease by setting diseased plants and by transferring infected soil to healthy fields.

It is not intended to review critically the whole club-root problem in this bulletin, but rather to present in connected form certain experimental data collected during the last three seasons at this Station. Only such literature as bears directly on the data presented and the conclusions drawn will be reviewed.

The more important points to be discussed are:

1. Relative susceptibilities of crucifers to club-root.
2. Resistance of cabbage, radish and turnip to club-root.
3. Types of hypertrophy on different crucifers.
4. Prevention by soil treatment.
5. "Hilling up" as a means of aiding the plants to resist disease attacks.

A lot of market garden soil near Burlington, upon which cabbage, cauliflower, etc., have been grown commercially for many years, had become so badly infected that crucifers could not be profitably raised. It was a rich, light sandy loam in good tilth, with its water-table close to the surface. The Station was given free access to this property for its experimental studies. Part of this same land was used in the trials reported in a previous publication* on the susceptibility of crucifers to this disease; and the work herein reported is a continuation of that heretofore discussed.

*Cunningham, G. C. A partial report on "The Comparative Susceptibility of Cruciferous Plants to *Plasmodiophora brassicae*" was published in *Phytopathology*, Vol. II, No. 4, August, 1912.

1. RELATIVE SUSCEPTIBILITIES OF CRUCIFERS TO CLUB-ROOT

Since Woronin²⁴ showed that *Plasmodiophora brassicae* is a parasite of cabbage and certain other crucifers, the statement that most crucifers are susceptible to its attack has gradually found its way into literature. Some writers have gone so far as to claim that families other than the crucifers are susceptible. As previously mentioned Marchand¹⁴ describes a disease of certain varieties of the *Cucurbitaceae*, *Umbelliferae* and *Polygonaceae* which he claimed to be thus caused, which Gregnan¹⁰ later showed to be due to nematodes, *Heterodera radiculicola*. Similar galls on other plants are similarly caused and may be mistaken for club-root. There appears to be seven genera which are susceptible to the attack of the organism. Among those who have contributed to our knowledge on this phase of the problem are Woronin,²⁴ Zopf,²⁵ Sorauer,²¹ Frank,⁷ Halsted,¹¹ Ravn,¹⁸ Saccardo¹⁹ and Appel.²

According to Halsted, who has shown the wide range of susceptibility among the crucifers, the following species are affected: *Brassica oleracea* (cabbage), *Brassica Rapa* (turnip), *Raphanus sativus* (radish), *Sisymbrium officinale*, *Iberis umbellata*, *Matthiola incana* (stock), *Bursa (Capsella) bursa-pastoris* (shepherd's purse), the last three rarely. Appel and Werth² examined many crucifers growing on soil known to be infected and extended the list by adding *Erysimum strictum*, *Sisymbrium austriacum*, *Sisymbrium strictissimum*. Ravn has compiled a list including 19 genera, 8 of which are known to be susceptible to the attack of *P. brassicae* in Denmark. He added *Thlaspi arvense* and *Cheiranthus cheiri* to the list of known hosts.

There is, however, but little literature bearing upon the range and comparative amount of susceptibility among the *Cruciferae*. This is partially due to the fact that much information is covered up by the statement that most crucifers are susceptible, a statement which, while perhaps true, has little recorded testimony to support it, as is shown by the comparatively limited lists just cited.

In 1911 the land above described was used to study among other problems this question of comparative susceptibility of crucifers to the attack of *Plasmodiophora brassicae*. As many varieties of the genus as possible were obtained from divers sources. Each variety of seed was sown in several parts of the field in order so far as might be to eliminate the factor of soil variation. All the seed was sown directly in the field, except cauliflower and cabbage, which were started in uninfected soil. At intervals throughout the season, and just before the

seeds were mature, the plants were examined for the appearance, nature and extent of the disease. The plants were carefully dug with a fork and not pulled up, since many clubs on the lateral roots, particularly on radishes and turnip, were broken off if pulled.

Notes were made touching: (1) General appearance of plants; (2) number examined; (3) number badly clubbed; (4) number slightly clubbed; (5) number showing free or adventitious rootlets. The number and weight of solid, saleable cabbage heads were also determined.

Similar studies were carried out under identical conditions during the three seasons. The results appear in table I, which shows the comparative susceptibilities of various crucifers. They are arranged in the order of their susceptibility, beginning with the badly clubbed varieties.

TABLE I. SUSCEPTIBILITY OF CRUCIFERS TO CLUB-ROOT

Reference number	Plant examined	Number of plants examined	Percentage not clubbed	Percentage clubbed	Percentage badly clubbed	Percentage slightly clubbed
1	Alyssum Moellendorffianum	3	0	100.	100.	0
2	Brassica alba	503	0	100.	100.	0
3	Brassica Rapa (southern curled turnip) ..	584	0	100.	100.	0
4	Crambe cordifolia	3	0	100.	100.	0
5	Draba borealis	1	0	100.	100.	0
6	Draba cuspidata	3	0	100.	100.	0
7	Iberis sp—(schneeflocke)	2	0	100.	100.	0
8	Neslia paniculata	97	0	100.	100.	0
8a	Camelina dentata	395	0	100.	99.6	0.6
9	Crambe tatarica	6	0	100.	50.	50.
10	Cardamine pratensis	1	0	100.	0	100.
11	Brassica arvensis	1,080	0.2	99.8	98.4	1.4
12	Brassica juncea	383	1.	99.	96.9	2.1
13	Mustard	112	1.8	98.2	98.2	0
14	Thlaspi arvense	167	2.4	97.6	94.	3.6
15	Lunaria biennis	36	2.8	97.2	91.6	5.6
16	Eruca sativa 31819*	321	3.7	96.3	92.8	3.5
17	Brassica campestris 26926*	430	4.4	95.6	90.2	5.4
18	Brassica oleracea var. caulo-rapa	1,406	4.7	95.3	79.8	15.5
19	Brassica oleracea 26564*	227	5.2	94.8	94.8	0
20	Camelina microcarpa	73	5.5	94.5	69.9	24.6
21	Brassica oleracea var. capitata	4,721	6.9	93.1	74.4	18.7
22	Brassica oleracea var. acephala	3,129	7.2	92.8	66.1	26.7
23	Iberis umbellata alba	224	8.	92.	80.8	11.2
24	Brassica oleracea var. botrytis	3,237	11.2	88.8	61.3	24.5
25	Brassica oleracea var. gemmifera	467	11.8	88.2	86.8	1.4
26	Iberis amara	117	13.	87.	75.7	11.3
27	Alyssum rostratum	15	13.3	86.7	60.	26.7
28	Erysimum parviflorum	14	14.3	85.7	85.7	0
29	Brassica napus (rape)	2,288	16.3	83.7	32.5	51.2
30	Brassica oleracea 21033*	76	18.4	81.6	81.6	0
31	Sisymbrium incisum	32	18.7	81.3	81.3	0
32	Camelina sativa	5	20.	80.	40.	40.
33	Mustard 32416*	81	21.	79.	76.6	2.4
34	Brassica (large flat green turnip) 25592* ..	89	22.5	77.5	71.8	5.7
35	Erysimum Barbarea	207	23.7	76.3	27.5	48.8
36	Cheiranthus allionii	21	23.8	76.2	71.4	4.8
37	Iberis coronaria	319	26.3	73.7	70.5	3.2
38	Conringia orientalis	1,067	27.6	72.4	29.7	42.7
39	Erysimum cheiranthoides	422	27.9	72.1	46.7	25.4
40	Barbarea vulgaris	97	29.9	70.1	0	70.1
41	Isatis glauca	19	31.6	68.4	36.8	31.6
42	Crambe maritima	88	31.8	68.2	51.2	17.
43	Aubrieta purpurea	65	32.3	67.7	67.7	0
44	Eruca sativa 31820*	624	37.	63.	59.8	3.2
45	Erysimum ockroleucum	7	42.8	57.2	28.6	28.6
46	Sophia pinnata	52	46.1	53.9	53.9	0
47	Iberis hybrida	213	47.4	52.6	30.	21.6
48	Arabis alpina	21	47.6	52.4	42.8	9.6
49	Lepidium apetalum	25	48.	52.	16.	36.
50	Alyssum argenteum	37	48.6	51.4	18.9	32.5
51	Alyssum maritimum	6	50.	50.	50.	0

TABLE I—Continued.

Reference number	Plant examined	Number of plants examined	Percentage not clubbed	Percentage clubbed	Percentage badly clubbed	Percentage slightly clubbed
52	<i>Draba fladnizensis</i>	2	50.	50.	50.	0
53	<i>Erysimum asperum</i>	16	50.	50.	31.2	18.8
54	<i>Arabis Holboellii</i>	2	50.	50.	0	50.
55	<i>Brassica napus</i>	264	50.8	49.2	10.2	39.
56	<i>Iberis lagascana</i>	110	52.7	47.3	7.3	40.
57	<i>Cheiranthus maritimus</i>	101	56.4	43.6	4.9	38.7
58	<i>Iberis sempervirens</i>	23	56.5	43.5	17.4	26.1
59	<i>Lepidium campestre</i>	271	57.2	42.8	30.3	12.5
60	<i>Isatis tinctoria</i>	40	57.5	42.5	17.5	25.
61	<i>Iberis odorata</i>	349	58.4	41.6	15.5	26.1
62	<i>Lobularia maritima</i>	682	58.8	41.2	35.2	6.
63	<i>Capsella bursa-pastoris</i>	209	59.2	40.8	13.6	27.2
64	<i>Sisymbrium officinale</i>	18	60.	40.	16.	24.
65	<i>Sisymbrium altissimum</i>	347	61.7	38.3	30.5	7.8
66	<i>Aubrieta Leichlini</i>	8	62.5	37.5	25.	12.5
67	<i>Raphanus sativus</i>	15,908	62.6	37.4	30.8	6.6
68	<i>Alyssum condensatum</i>	12	66.6	33.4	16.7	16.7
69	<i>Hesperis matronalis</i>	268	67.9	32.1	7.8	24.3
70	<i>Alyssum saxatile</i>	156	68.	32.	1.3	30.7
71	<i>Brassica nigra</i>	249	71.8	28.2	23.3	4.9
72	<i>Brassica campestris</i> (wild)	330	77.	23.	16.7	6.3
73	<i>Lepidium virginicum</i>	122	77.	23.	5.7	17.3
74	<i>Alyssum montanum</i>	9	77.8	22.2	22.	0
75	Everlasting radish	27	77.8	22.2	18.5	3.7
76	<i>Brassica Rapa</i>	123	87.2	12.8	10.4	2.4
77	<i>Brassica campestris</i> (cultivated)	494	88.2	11.8	5.1	6.7
78	<i>Brassica Rapa</i> 22755*	393	89.1	10.9	8.4	2.5
79	<i>Alyssum serpyllifolium</i>	36	91.7	8.3	8.3	0
80	<i>Crambe hispanica</i>	78	93.7	6.3	3.8	2.5
81	<i>Barbarea stricta</i>	69	95.7	4.3	1.4	2.9
82	<i>Matthiola bicornis</i>	187	95.7	4.3	0	4.3
83	<i>Iberis zenoreana</i>	44	97.7	2.3	2.3	0
84	<i>Erysimum helveticum</i>	49	97.9	2.1	2.1	0
85	<i>Lepidium sativum</i>	223	98.2	1.8	.9	.9
86	<i>Alyssum Wierzbickii</i>	12	100.	0	0	0
87	<i>Arabis Halleri</i>	2	100.	0	0	0
88	<i>Aubrieta Bougainvillei</i>	13	100.	0	0	0
89	<i>Aubrieta eyrei</i>	2	100.	0	0	0
90	<i>Aubrieta graeca</i>	18	100.	0	0	0
91	<i>Aubrieta Hendersoni</i>	4	100.	0	0	0
92	<i>Barbarea vulgaris</i>	97	100.	0	0	0
93	<i>Cheiranthus incanus</i>	55	100.	0	0	0
94	<i>Draba armata</i>	12	100.	0	0	0
95	<i>Draba caroliniana</i>	4	100.	0	0	0
96	<i>Erysimum comatum</i>	146	100.	0	0	0
97	<i>Matthiola tricuspidata</i>	204	100.	0	0	0
98	<i>Draba androsacea</i> **	0	100.	0	0	0

*Seeds which have been lately introduced into the United States by the Bureau of Plant Industry; figures indicate B. P. I. accession number.

**These plants form masses of tufted moss-like vegetation lying close to the surface of the ground. They were grown on infected soil for one year and have never shown clubbing during that time.

TABLE II. SUSCEPTIBILITY OF CRUCIFERS TO CLUB-ROOT (ALPHABETICALLY ARRANGED)

Reference number	Plant examined	Total number plants examined	Number not clubbed	Number badly clubbed	Number slightly clubbed	Percentage not clubbed	Percentage badly clubbed	Percentage slightly clubbed
50	Alyssum argenteum	37	18	7	12	48.6	18.9	32.5
68	" condensatum	12	8	2	2	66.6	16.7	16.7
51	" maritimum	6	3	3	0	50.	50.	0
1	" Moellendorffianum	3	0	3	0	0	100.	0
74	" montanum	9	7	2	0	77.8	22.2	0
27	" rostratum	15	2	9	4	13.3	60.	26.7
70	" saxatile	156	106	2	48	68.	1.3	30.7
79	" serpyllifolium	36	33	3	0	91.7	8.3	0
86	" Wierzbickii	12	12	0	0	100.	0	0
48	Arabis alpina	21	10	9	2	47.6	42.8	9.6
87	" Halleri	13	13	0	0	100.	0	0
54	" Holboellii	2	1	0	0	50.	0	50.
88	Aubrietia Bougainvillei	13	13	0	0	100.	0	0
89	" eyrei	2	2	0	0	100.	0	0
90	" graeca	18	18	0	0	100.	0	0
91	" Hendersoni	4	4	0	0	100.	0	0
66	" Leichtlini	8	5	2	1	62.5	25.	12.5
43	" purpurea	65	21	44	0	32.3	67.7	0
81	Barbarea stricta	69	66	1	2	95.7	1.4	2.9
92 & 40	" vulgaris	97	29	0	68	29.9	0	70.1
2	Brassica alba	503	0	503	0	0	100.	0
11	" arvensis	1,080	2	1,063	15	.2	98.4	1.4
34	" campestris (large flat green turnip 25592)*	89	20	64	5	22.5	71.8	5.7
17	" campestris 26926* (fr. India)	430	19	388	23	4.4	90.2	5.4
77	" campestris (cultivated turnip)	494	436	25	33	88.2	5.1	6.7
72	" campestris (wild)	330	254	55	21	77.	16.7	6.3
12	" juncea	383	4	371	8	1.	96.9	2.1
29	" napus (rape)	2,288	374	745	1,169	16.3	32.5	51.2
55	" napus	264	134	27	103	50.8	10.2	39.
71	" nigra	249	179	58	12	71.8	23.3	4.9
18	" oleracea var. caulo-rapa (Kohlrabi)	1,406	66	1,121	219	4.7	79.8	15.5
19	" " 26564*	227	12	215	0	5.2	94.8	0
21	" " var. capitata (cabbage)	4,721	326	3,512	883	6.9	74.4	18.7
22	" " var. acephala (collards)	3,129	225	2,067	837	7.2	66.1	26.6
24	" " var. botrytis	3,237	361	1,982	794	11.2	61.3	24.5
25	" " var. gemmifera	467	55	408	6	11.8	86.8	1.4
30	" " 21033*	76	14	62	0	18.4	81.6	0
78	" Rapa 22755*	393	350	33	10	89.1	8.4	2.4
3	" Rapa (southern curled)	584	0	584	0	0	100.	0
76	" Rapa	123	120	0	3	87.6	0	2.4
8a	Camelina dentata	395	0	393	2	0	99.4	0.6
20	" " microcarpa	73	4	51	18	5.5	69.9	24.4
32	" " sativa	5	1	2	2	20.	40.	40.
63	Capsella bursa-pastoris	209	0	59.2	40.8	0	13.6	27.4
10	Cardamine pratensis	1	0	0	1	0	0	100.
36	Cheiranthus allionii	21	5	15	1	23.8	71.4	4.8
93	" " incanus	55	55	0	0	100.	0	0
57	" " maritimus	101	57	5	39	56.4	4.9	38.7

TABLE II—Continued

Reference number	Plant examined	Total number plants examined	Number not clubbed	Number badly clubbed	Number slightly clubbed	Percentage not clubbed	Percentage badly clubbed	Percentage slightly clubbed
33	<i>Conringia orientalis</i>	1,067	294	317	456	27.6	29.7	42.7
4	<i>Crambe cordifolia</i>	3	0	3	0	0	100.	0
80	<i>hispanica</i>	78	73	3	2	93.7	3.8	2.5
42	<i>maritima</i>	88	28	45	15	31.8	51.2	17.
9	<i>tatarica</i>	6	0	3	3	0	50.	50.
5	<i>Draba borealis</i>	1	0	1	0	0	100.	0
95	<i>caroliniana</i>	4	4	0	0	100.	0	0
6	<i>cuspidata</i>	3	0	3	0	0	100.	0
52	<i>fladikensis</i>	2	1	1	0	50.	50.	0
98	<i>androsacea</i> **	0	100	0	0	100.	0	0
94	<i>armata</i>	12	12	0	0	100.	0	0
53	<i>Erysimum asperum</i>	16	8	5	3	50.	31.	18.8
35	<i>Barbarea</i>	207	49	57	101	23.7	27.5	48.8
39	<i>chelranthoides</i>	422	118	197	107	27.9	46.7	25.4
96	<i>comatum</i>	146	146	0	0	100.	0	0
84	<i>helveticum</i>	49	48	1	0	97.9	2.1	0
45	<i>ochroleucum</i>	7	3	2	2	42.8	28.6	28.6
28	<i>parviflorum</i>	14	2	12	0	14.3	85.7	0
16	<i>Eruca sativa</i> 31819*	321	12	298	11	3.7	92.8	3.5
44	" 31820*	624	231	373	20	37.	59.8	3.2
75	<i>Everlasting radish</i>	27	21	5	1	77.8	18.5	3.7
69	<i>Hesperis matronalis</i>	268	182	21	65	67.9	7.8	24.3
26	<i>Iberis amara</i>	117	23	134	20	13.	75.7	11.3
37	<i>coronaria</i>	319	84	225	10	26.3	70.5	3.2
47	<i>hybrida</i>	213	101	64	48	47.4	30.	21.6
56	<i>lagascana</i>	110	58	8	44	52.7	7.3	40.
61	<i>odorata</i>	349	204	54	91	58.4	15.5	26.1
7	<i>sp.—(schneeflocke)</i>	2	0	2	0	0	100.	0
58	<i>sempervirens</i>	23	13	4	6	56.5	17.4	26.1
23	<i>umbellata alba</i>	224	18	181	25	8.	80.8	11.2
53	<i>zenoreana</i>	44	43	1	0	97.7	2.3	0
41	<i>Isatis glauca</i>	19	6	7	6	31.6	36.8	31.6
60	<i>tinctoria</i>	40	23	7	10	57.5	17.5	25.
49	<i>Lepidium apetalum</i>	25	12	4	9	48.	16.	36.
59	<i>campestre</i>	271	155	82	34	57.2	30.3	12.5
85	<i>sativum</i>	223	219	2	2	98.2	.9	.9
73	<i>virginicum</i>	122	94	7	21	77.	5.7	17.3
62	<i>Lobularia maritima</i>	682	401	240	41	58.8	35.2	6.
15	<i>Lunaria biennis</i>	36	1	33	2	2.8	91.6	5.6
82	<i>Matthiola bicornis</i>	187	179	0	8	95.7	0	4.3
97	<i>tricuspidata</i>	204	204	0	0	100.	0	0
13	<i>Mustard</i>	112	2	110	0	1.8	98.2	0
33	<i>Mustard</i> 32416*	81	17	62	2	21.	76.6	2.4
5	<i>Neslia paniculata</i>	97	0	97	0	0	100.	0
67	<i>Raphanus sativus</i>	15,908	9,966	4,901	1,041	62.6	30.8	6.6
65	<i>Sisymbrium altissimum</i>	347	214	106	27	61.7	30.5	7.8
31	" <i>incisum</i>	32	6	26	0	18.7	81.3	0
64	" <i>officinale</i>	18	10	8	60	40.	16.	24.
46	<i>Sophia pinnata</i>	52	24	28	0	46.1	53.9	0
14	<i>Thlaspi arvense</i>	167	4	157	6	2.4	94.	3.6

*Seeds which have been lately introduced into the United States by the Bureau of Plant Industry; figures indicate B. P. I. accession number.

**These plants form masses of tufted moss like vegetation lying close to the surface of the ground. They were grown on infected soil for one year and have never shown clubbing during that time.

An examination of tables I and II confirms the popular opinion that most of the *Cruciferae* are more or less susceptible to club-root. Certainly all of the more common varieties or species are susceptible. The 11 species which appear free from the disease are for the most part rare and practically are never cultivated. Furthermore it should be noted that comparatively few specimens of these species were examined. It is not at all unlikely that a more extended examination would disclose a greater or less number of infected individuals. There is a wide range of susceptibility, not only among the genera but among the species within the genera, and to an equal extent among the varieties of the same species. This fact is manifested by the wide scattering of the names of the different species of the same genera throughout the table. Thus one variety of *Brassica Rapa* shows 100 percent badly clubbed while another shows only 10.9 percent clubbed. A similar condition exists among the *Lepidiums* *L. incisum*, 81 percent clubbed, *L. sativum*, 1.2 clubbed; other illustrations occur among *Alyssum*, *Aubrietia*, *Draba*, *Erysimum* and *Iberis*; and the list might be greatly extended.

A similar diversity exists among the different varieties or strains of the same species, as is indicated by data in tables III-XI which deal with the resistance to clubbing of different varieties of cabbages, radishes and turnips (pages 77-88). Thus the Mammoth Rock Red cabbage was 100 percent clubbed and the Hollander 74 percent; and similar and wider variations exist among radishes and turnips.

2. RESISTANCE OF CABBAGES, TURNIPS AND RADISHES TO CLUB-ROOT

The question of resistant varieties of cultivated crucifers has received little attention from research students, save some fragmentary studies on a few varieties of turnips made for the most part in the British Isles. Hence the writer has studied the club-root resistance of cabbages, turnips and radishes, with a view of securing data.

CABBAGES

During 1911, 13 varieties of cabbage were grown on diseased soil. The plants were started on club-root free soil and transplanted late in June. They were at first set in rows 12 inches apart each way, and, later, thinned, leaving but one plant for each 2 square feet, or 60 in each 10 x 12 plot. They were hand cultivated. Notes were made at thinning time as to disease resistance. Four or more plots were planted of each variety.

When dug for examination, the total numbers, the total numbers badly clubbed and the total numbers slightly clubbed were recorded. A badly clubbed plant was deemed to be one where the main root and the greater part of the lateral roots were diseased; a slightly clubbed plant, one where the main root was for the most part free from disease, while at the same time less than half of the laterals were healthy. Sharp lines could not be drawn in all cases. When harvested in the fall, the total weights and the numbers and weights of saleable heads were recorded.

Tables III, IV and V display these data, the varieties being arranged in the latter according to (1) relative clubbing of roots, (2) number of saleable heads, and (3) weight of saleable heads.

TABLE III. CABBAGE. RESISTANCE OF VARIETIES TO CLUB-ROOT (1911), AS REVEALED BY DISEASED ROOTS

Variety	Total number examined	Percentage not clubbed	Percentage clubbed	Percentage badly clubbed	Percentage slightly clubbed
Mammoth Rock Red	275	0	100.	97.1	2.9
Perfection Savoy	279	0	100.	92.5	7.5
American Savoy	249	0.8	99.2	80.	19.2
Dark Red Erfurt	238	1.2	98.8	86.6	12.2
All Seasons	654	2.7	97.3	88.8	8.5
Henderson's Early Summer	356	5.6	94.4	72.	22.5
Early Winningstadt	339	5.6	94.4	63.7	30.7
Charleston (Early Wakefield).....	304	5.9	94.1	74.6	19.5
Volga	546	8.8	91.2	82.	9.2
Early Jersey Wakefield	274	9.4	90.6	47.5	43.1
Large Late Flat Dutch	486	9.9	90.1	62.6	27.6
Stone Mason	180	14.4	85.6	65.6	20.
Hollander	540	26.5	73.5	52.6	20.9

TABLE IV. CABBAGE. RESISTANCE OF VARIETIES TO CLUB-ROOT (1911), AS REVEALED BY NUMBERS AND WEIGHTS OF SALEABLE HEADS

Variety	Number of plants living at the time of examination	Number of saleable heads	Weight of saleable heads	Number of saleable heads per acre	Weight of saleable heads per acre
All Seasons	202	4	8	724	1,448
Volga	162	7	10	1,267	1,810
Mammoth Rock Red	199	33	27	5,973	4,887
Dark Red Erfurt	?	14	29	2,534	5,249
Early Jersey Wakefield	133	32	54	5,792	9,774
Early Winningstadt	128	62	58	11,222	10,498
American Savoy	?	52	63	9,412	11,403
Perfection Savoy	?	44	64	7,964	11,584
Charleston, (Early Wakefield).....	90	35	79	6,335	14,299
Large Late Flat Dutch	120	34	79.5	6,154	14,389
Hollander	153	39	83	7,059	15,023
Henderson's Early Summer	103	59	91.5	10,679	16,561
Stone Mason	105	43	108	17,783	19,548

TABLE V. CABBAGE. RESISTANCE DATA ARRANGED ACCORDING TO CLUBBING OF ROOTS, NUMBER OF SALEABLE HEADS AND WEIGHT OF SALEABLE HEADS

	Clubbing of roots	Number of saleable heads	Weight of saleable heads
1	Mammoth Rock Red	All Seasons	All Seasons
2	Perfection Savoy	Volga	Volga
3	American Savoy	Dark Red Erfurt	Mammoth Rock Red
4	Dark Red Erfurt	Early Jersey Wakefield	Dark Red Erfurt
5	All Seasons	Mammoth Rock Red	Early Jersey Wakefield
6	Henderson's Early Summer	Large Late Flat Dutch	Early Winningstadt
7	Early Winningstadt	Charleston	American Savoy
8	Charleston	Hollander	Perfection Savoy
9	Volga	Stone Mason	Charleston
10	Early Jersey Wakefield	Perfection Savoy	Large Late Flat Dutch
11	Large Late Flat Dutch	American Savoy	Hollander
12	Stone Mason	Henderson's Early Summer	Henderson's Early Summer
13	Hollander	Early Winningstadt	Stone Mason

It is hard to say just how thoroughly reliable conclusions may be drawn as to the susceptibility of cabbages to club-root. The above tables arrange the data in relation to three important factors, namely: (1) percentage of plants diseased, (2) number of saleable heads, (3) weight of saleable heads. These varieties do not show a very great difference in the percentage of diseased plants. They do show, however, greater variation in the number of saleable heads and a still greater difference in the weight of saleable cabbage. These last two

factors, however, are not wholly dependent on the presence or the activity of the disease. Thus some varieties are naturally either poor or good headers, while some usually produce small heads and others large heads, some solid heads and others loose heads. Furthermore, it must be remembered that the weight of saleable cabbages is not the only factor which the grower must consider; the date of maturity, the size and shape of the head and the quality are equally important.

The data here presented show: (1) that susceptibility to the disease varied from 73.5 to 100 percent diseased; (2) that the number of saleable heads varied from 11,222 to only 724 heads per acre; and (3) that the weight of saleable heads varied from 19,548 pounds to only 1,448 pounds per acre. These results are undoubtedly influenced by the disease, but they are also dependent on natural variation in the type of plant. Some varieties of cabbages are more susceptible than others, but this fact is not distinctly indicated by any one factor, being on the contrary betrayed by several factors; and all three of the tables given above, together with a knowledge of the normal growth of the variety must be taken into account in order to appreciate any resistance which may be present. It seems safe to say, however, that the red varieties, the Savoy, All Seasons and Volga, are among the more susceptible, while the Hollander, Stone Mason, Large Late Flat Dutch and Henderson's Early Summer are among the more resistant.

RADISHES

Several varieties of radish were grown in 1911. It was then noticed that some seemed more resistant towards clubbing than others. A dozen or more varieties were sown in 1912 and again in 1913 in order to determine their relative resistance, being grown in parallel rows on badly infected but apparently uniform soil. The radishes were examined when, or a little after, they were ready for table use. They were dug with a fork and the soil carefully removed without breaking off many of the clubs.

Table VI shows the results attained with 13 varieties in 1912, arranged in the order of their susceptibilities; and table VII, similar data for 1913.

TABLE VI. RADISHES. RESISTANCE OF VARIETIES TO CLUB-ROOT (1912)

Varieties	Total number examined	Not clubbed %	Clubbed %	Badly clubbed %	Slightly clubbed %
Early Long Scarlet	377	7.7	92.3	91.2	1.1
Round Black Spanish	1,020	34.1	65.9	56.1	9.8
Radish 30194 from West China*	320	34.4	65.6	59.4	6.2
French Breakfast	1,177	38.	62.	56.8	5.2
Radish var. unknown	437	41.4	58.6	38.7	19.9
Everlasting 10399* from Santa Clara, Cal.	483	46.2	53.8	0	53.8
Radish 30193 from Yachow, West China*	580	46.6	53.4	53.4	0
Red Radish 25593 from China*.	176	46.6	53.4	43.7	9.7
Early Scarlet Turnip	769	53.7	46.3	39.3	7.
White Tip	471	54.	46.	35.4	10.6
Long Black Spanish	2,309	73.	27.	22.9	4.1
Giant	672	83.1	16.9	11.3	5.6
Giant Stuttgart	1,612	94.4	5.6	3.8	1.8

*U. S. Dept. Agr., Bu. Pl. Ind., accession number.

TABLE VII. RADISHES. RESISTANCE OF VARIETIES TO CLUB-ROOT (1913)

Varieties	Total number examined	Not clubbed %	Clubbed %	Badly clubbed %	Slightly clubbed %
Early Long Scarlet	139	12.2	87.8	79.9	7.9
Early Scarlet Globe	425	41.6	58.4	42.9	15.5
Chinese Rose Winter	214	48.6	51.4	40.7	10.7
Early Scarlet Turnip White Tip..	302	59.	41.	27.4	13.6
Chartier	163	59.5	40.5	24.5	16.
Scarlet China Winter	691	59.9	40.1	16.1	24.
French Breakfast	481	68.	32.	22.5	9.6
Long White Vienna	267	76.2	23.8	21.	2.8
Round Red Turnip	359	83.	17.	15.	2.
Round Black Spanish	471	89.4	10.6	7.6	3.
Crimson Giant	492	90.2	9.8	7.3	2.4
Improved Chartier	566	90.6	9.4	3.8	5.6
Icicle	680	95.4	4.6	2.4	2.2
White Giant Stuttgart	481	95.8	4.2	2.7	1.5
Ne Plus Ultra	421	96.8	3.2	1.7	1.5
Early Scarlet Turnip	338	98.2	1.8	.3	1.5

A wide range of susceptibility appeared among the cultivated varieties of radishes, varying from the Long Scarlet Radish (92.3 per cent clubbed) to the Giant Stuttgart (5.6 percent clubbed). It is interesting to note the extreme divergence of results observed between the Long Black and the Round Black Spanish, the former displaying 27 percent and the latter 66 percent of clubbing. One variety, Everlasting (10399), introduced by the Bureau of Plant Industry from Santa Clara, California, was not badly clubbed. It is a long white-fleshed radish of fine quality but strong flavored. It is edible through-



PLATE I. Club-root of cabbage, showing swollen and distorted roots and undeveloped head.

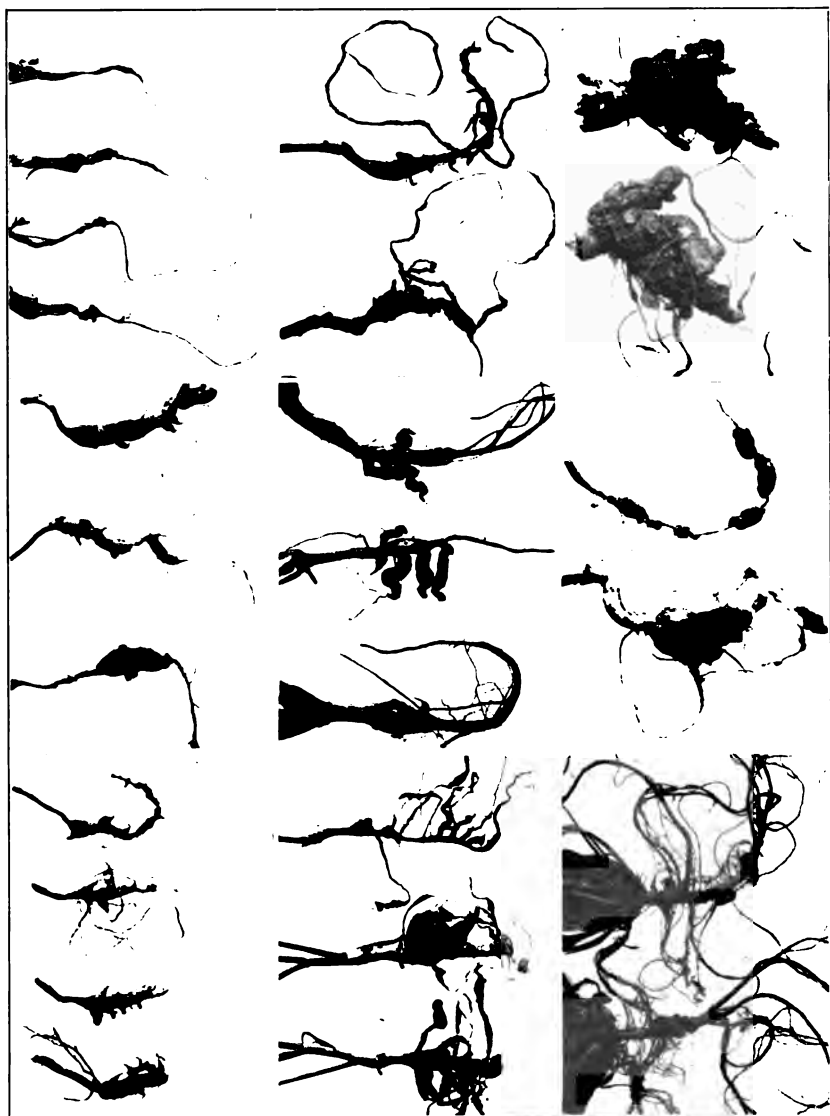


PLATE II.

Capsella bursa-pastoris.
Eruca sativa.
Nastella paniculata.

Brassica juncea.
Crambe maritima.
Brassica nigra.

Iberis coronaria.
Camelinea dentata.
Lepidium campestris.

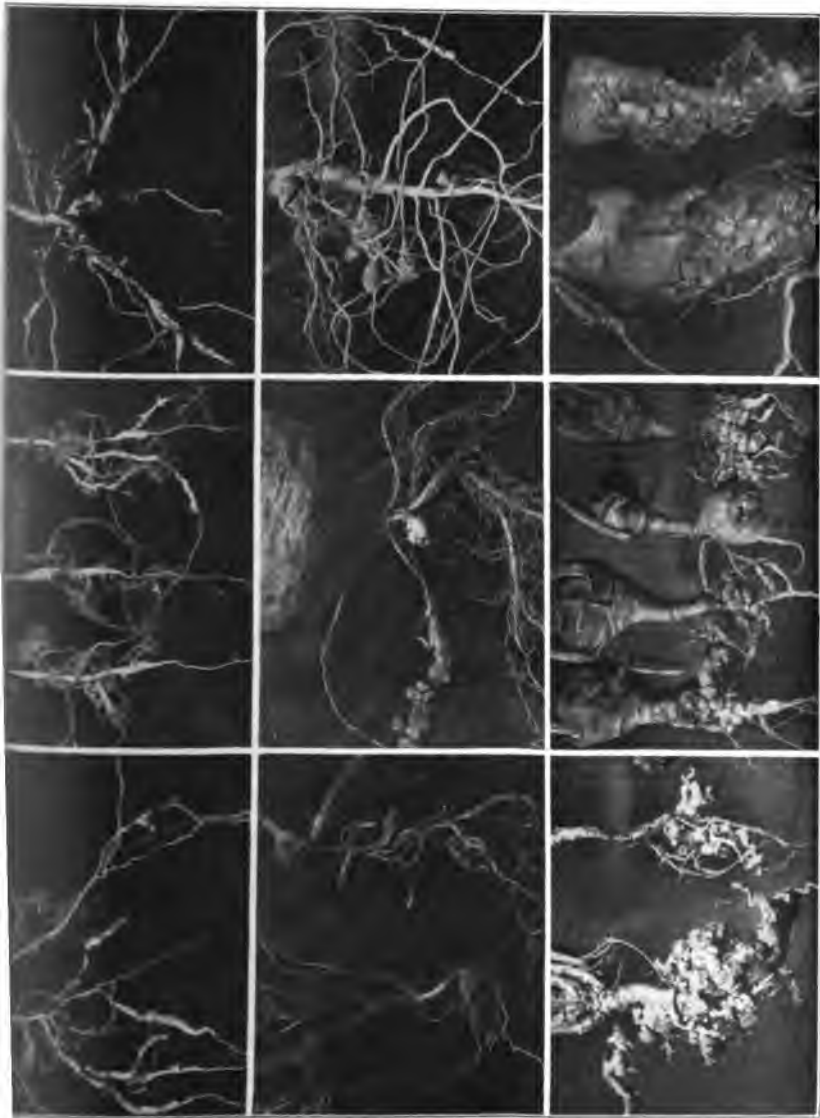


PLATE III.

Erysimum cheiranthoides,
Brassica Rapa,
Brassica oleracea.

Erysimum asperum,
Lepidium apetalum,
Brassica campestris,

Arabis alpina.
Sisymbrium altissimum.
Raphanus sativus.



PLATE IV. *Brassica arvensis* (upper); *Brassica campestris* (lower).



PLATE V. *Raphanus sativus*. Upper section, common type of clubbing; lower section, tumors embedded in tissue.

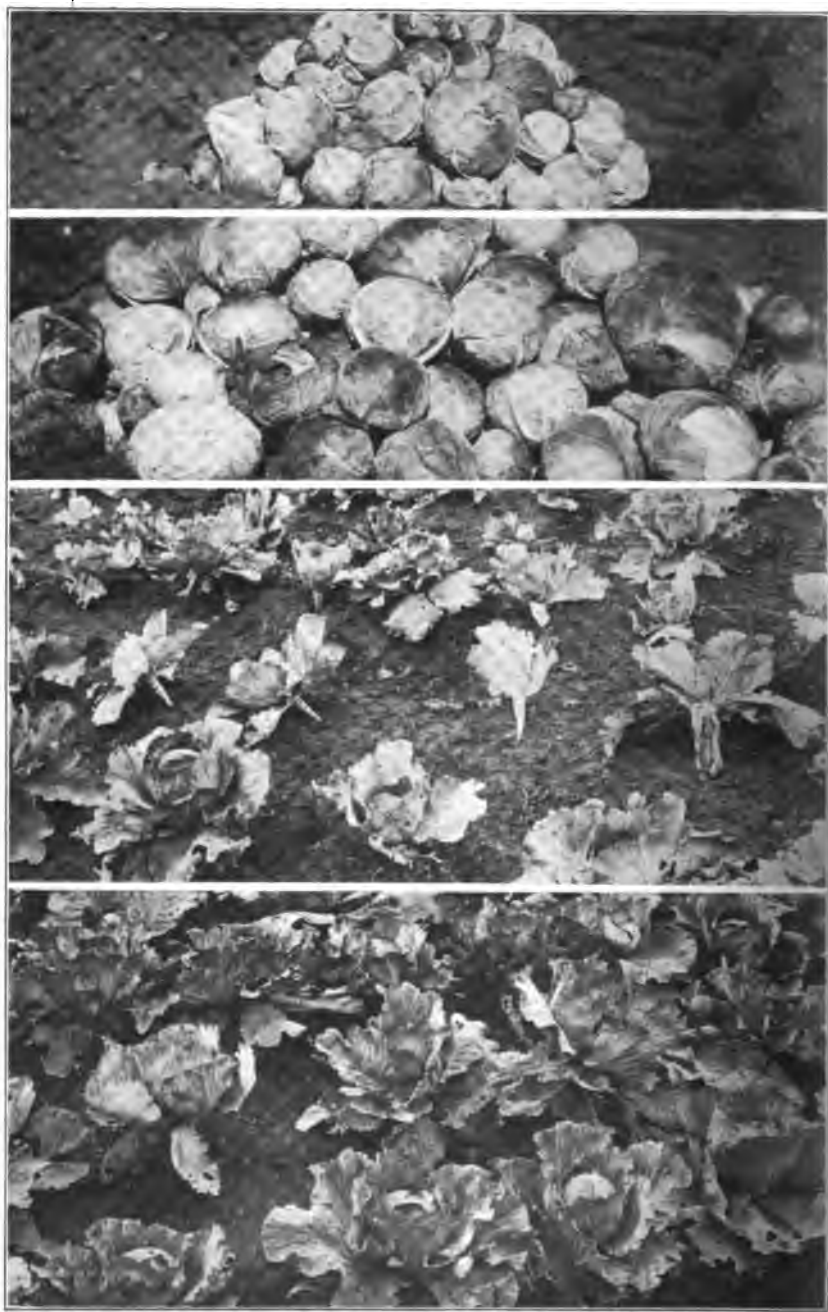


PLATE VI. Air-slaked lime as a preventive of club-root.
Smaller yields unlimed; larger yields limed.



PLATE VII. Turnips. Effect of nematodes. (*Heterodera radiculola*).

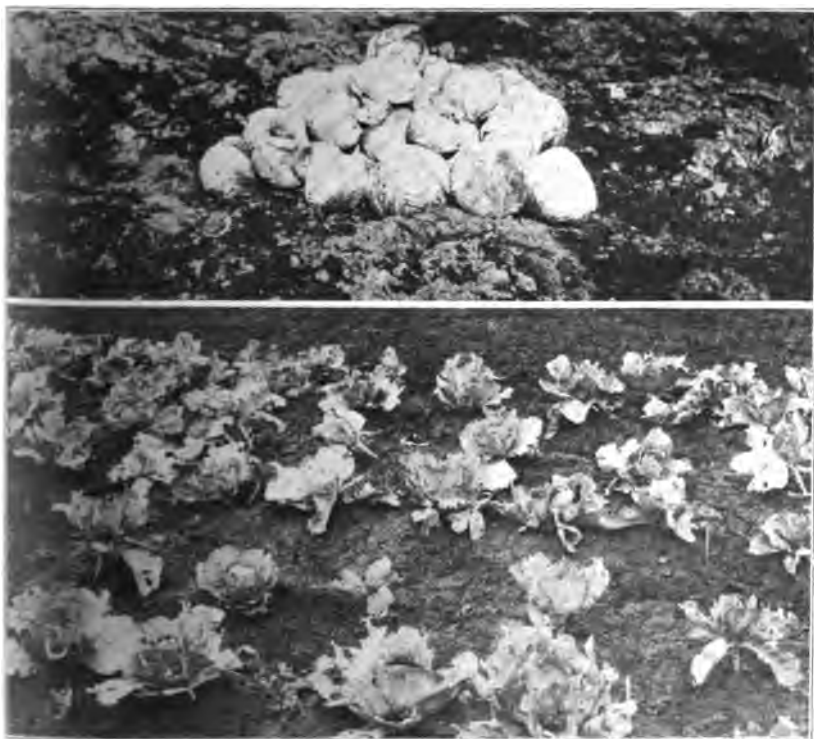
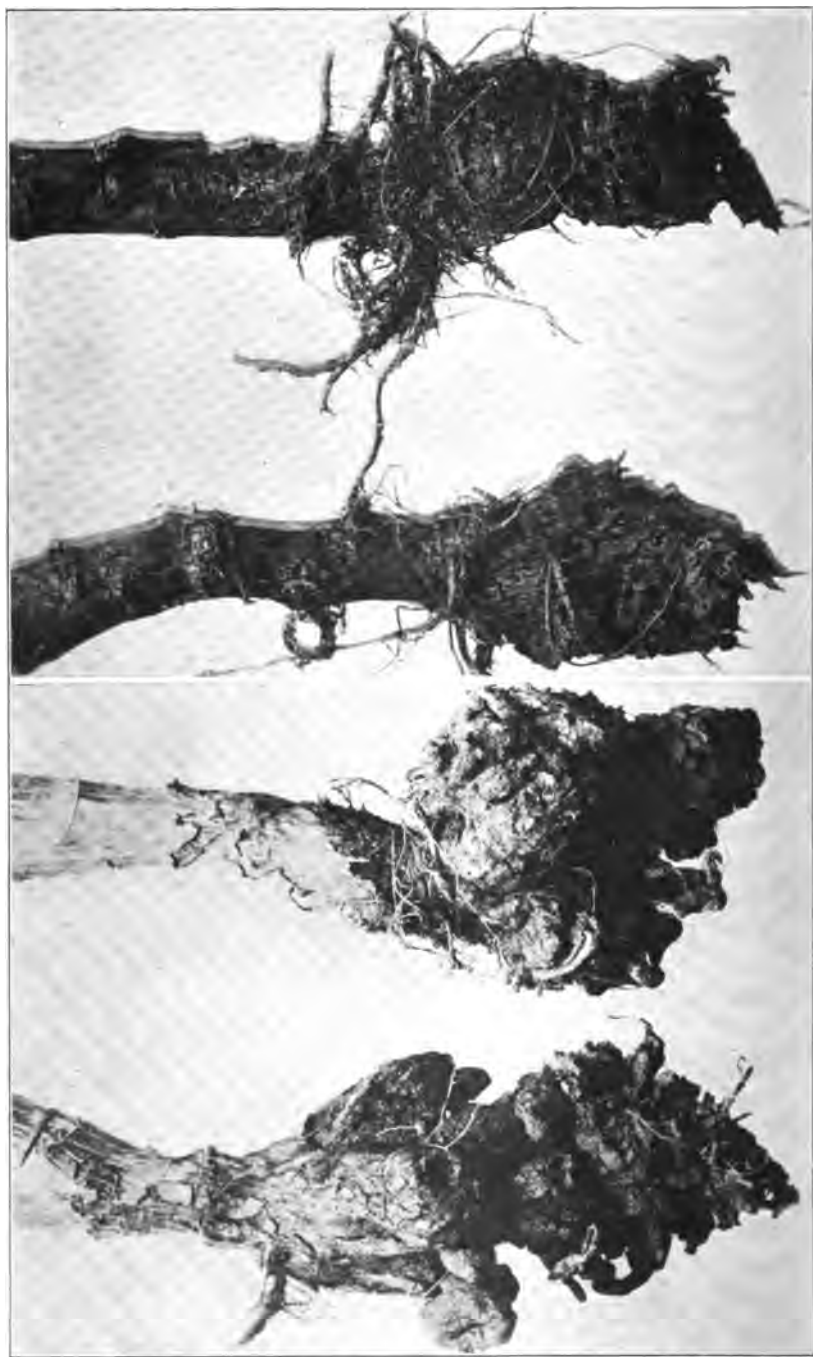


PLATE VIII. Calcium chlorid ineffectual as a preventive of club-root.



Unhilled. Hilled.
PLATE IX. Effect of hilling on lateral root formation (page 91).

out the season. More than half the crop was slightly clubbed, but the clubs were always located on the lateral roots, so that the radishes were not materially injured for table use. Late in the season this variety often exhibits blackened spots in the flesh, which Appel and Werth² claim is a form of the disease characteristic of radish. Radish 25593 showed 8.9 percent badly and 20 percent slightly clubbed. Over half of the diseased plants of all other varieties were badly clubbed. Similar conclusions may be drawn from the data displayed in table VII which records the results attained in 1913.

Clubbing of radishes seemed to be more severe in 1912 than in 1913. This may have been due to climatic or to seasonal conditions, or to conditions more or less unappreciated. The seed was sown earlier in 1912. Comparisons appear below.

TABLE VIII. RADISHES. RESISTANCE OF CERTAIN VARIETIES TO CLUB-ROOT

Varieties	1912		1913	
	Clubbed %	Badly clubbed %	Clubbed %	Badly clubbed %
Early Long Scarlet	92.3	91.2	87.8	79.9
Round Black Spanish	65.9	56.1	10.6	7.6
French Breakfast	62.	56.8	32.	22.5
White Giant Stuttgart	5.6	3.8	4.2	2.7
Early Scarlet Turnip	46.3	39.3	1.8	.3

The same varieties grown during the two seasons tend roughly to show parallelism of results. Early Long Scarlet was the most susceptible variety each year and Early Giant Stuttgart and Early Scarlet Turnip the least susceptible. These results seem to warrant the conclusion that some varieties may prove to be more resistant than others.

TURNIPS

Several varieties of turnips, both true turnips and rutabagas, were sown in 1912 and 1913 in rows on badly infected soil and under the same conditions as obtained with the cabbages and radishes. The turnip, *Brassica Rapa*, is a thick, light-fleshed root, usually more or less flattened or at least not greatly elongated, with hairy but not glaucous leaves. The rutabaga, *Brassica campestris*, on the other hand, is a yellow-fleshed root, more uniformly elongated, with fine rootlets extending from the lower portion of the root, a thick, elongated, leafy neck, and glaucous blue, smooth leaves.

Tables IX and X show the comparative susceptibilities of the several varieties tested, arranged in the order of their susceptibilities. The classification is indicated by the letter T—turnip (*B. Rapa*), or R—rutabaga (*B. campestris*), in each case. It is often hard to say where a given variety belongs, especially since trade names are quite unreliable.

TABLE IX. TURNIPS AND RUTABAGAS. RESISTANCE OF VARIETIES TO CLUB-ROOT (1912)

Varieties	Total number examined	Not clubbed %	Clubbed %	Badly clubbed %	Slightly clubbed %
Southern Curled Turnip.....T	584	0	100.	100.	0
Rutabaga (from India, 26926)*	274	4.3	95.7	95.7	0
Large flat green turnip (from China, 25592)*	89	22.5	77.5	72.	5.5
Petrowski Turnip (from Finland, 22755)*.....R	208	87.5	12.5	10.1	2.4
Turnip (from Ottawa, Canada)	484	88.	12.	5.2	6.8
Turnip (uncultivated)	217	94.5	5.5	0	5.5
Purple Yellow Top	3,317	97.3	2.7	.5	2.2
Rutabaga	237	98.7	1.3	0	1.3
Early White Milan	608	98.9	1.1	.8	.3
Sweet German	1,860	100.	0	0	0
White Swede	2,188	100.	0	0	0

*U. S. Dept. Agr., Bu. Pl. Ind., accession number.

TABLE X. TURNIPS AND RUTABAGAS. RESISTANCE OF VARIETIES TO CLUB-ROOT (1913)

Varieties	Total number examined	Not clubbed %	Clubbed %	Badly clubbed %	Slightly clubbed %
Rutabaga (from India, 26926)+	85	4.7	95.4	91.8	3.6
Rutabaga (from Canada).....R	160	65.	35.	26.2	8.8
Early Purple Top Straight Leaf	467	77.5	22.5	12.4	10.1
Improved Purple Top Straight Leaf	407	84.	16.	9.1	6.9
Wild turnip	170	88.3	11.8	7.7	4.1
Large Amber Globe	343	91.	9.	2.9	6.1
Petrowski (from Finland, 22755)*	13	92.2	7.8	7.8	0
Early White Milan	178	94.4	5.6	3.4	2.2
Early White Flat Dutch Strap Leaf	344	95.7	4.3	2.	2.3
White Egg	232	97.4	2.6	.9	1.7
Yellow Stone	273	97.5	2.5	.4	2.2
Turnip (from Canada).....T	123	97.6	2.4	0	2.4
Yellow Rutabaga	539	97.7	2.3	0	2.3
Early Snowball	679	99.4	.6	.3	.3
Purple Aberdeen	166	99.4	.6	0	.6
Sweet German	334	99.7	.3	0	.3
Sweet Russian	347	100.	0	0	0

*U. S. Dept. Agr., Bu. Pl. Ind., accession number.

An examination of tables IX and X shows that the range of susceptibility among the turnips is even greater than among the cabbages and radishes. The results during both years show variation all the way from almost 100 percent susceptible to 100 percent apparently immune. In 1912 (table IX) every specimen of Southern Curled Turnip was so badly clubbed that the roots did not resemble the characteristic fleshy turnip root but appeared as numerous branching hypertrophied rootlets. The rutabaga from India, 26926, was quite as misshapen as were the specimens of the variety just named, 96 percent of its roots being badly clubbed. The large, flat, green variety from China was also inferior in this respect. The other varieties were for the most part but slightly affected; two of them, (both rutabages) Sweet German and White Swede, being entirely free from clubbing, and two, (both turnips proper) Early White Milan and an unknown, almost free therefrom. The 1913 results are similar to those obtained in 1912. The Southern Curled Turnip which was the most severely diseased in 1912 was not tested again; but the second most severely diseased variety, a rutabaga from India, was again a victim, 95 percent of the plants being affected. As in the preceding year Sweet German was almost untouched, only 0.3 percent being clubbed; and Sweet Russian, a variety not tested in 1912, was entirely free from the disease. These results confirm the work of 1912 and indicate that there are varieties which are fairly resistant and others which are noticeably susceptible.

Where the same varieties were grown during both seasons, the order of their susceptibilities is not greatly changed. A variety which showed marked resistance in 1912 exhibited it again in 1913, as may be noted in the following table compiled from its immediate predecessors.

TABLE XL TURNIPS AND RUTABAGAS. RESISTANCE OF CERTAIN VARIETIES TO CLUB-ROOT

Varieties	1912		1913	
	Clubbed %	Badly clubbed %	Clubbed %	Badly clubbed %
Rutabaga (from India, 26926)*.....R	95.7	95.7	95.4	91.8
Petrowski (from Finland 22755)*....R	12.5	10.1	7.8	7.8
Early White Milan .....T	1.1	.8	5.6	3.4
Sweet German .....R	0	0	.3	0

*U. S. Dept. Agr., Bu. Pl. Ind., accession number.

Clearly Sweet German, White Swede, Early White Milan, Early Snowball and Purple Top Aberdeen may be expected to be relatively resistant and, among the more commonly cultivated varieties, Southern Curled, Early Purple Top Straight Leaved and Improved Purple Top Straight Leaved may be expected to be relatively susceptible to club-root.

Apparently the turnips proper as a class were somewhat more susceptible than the rutabagas, since 2 of the 3 varieties more than 75 percent of which were badly clubbed in 1912, were turnips, whereas 2 rutabagas were entirely free from clubbing (table IX). Almost equally resistant, however, were 2 turnips which show less than 2 percent clubbing. Essentially similar results were attained in 1913. While rutabagas as a class seem more resistant than turnips, no pronounced differences hold good for all varieties of either species. One should recall, however, the fact that it is impossible to draw any sharp line of demarkation between turnips and rutabagas.

Anderson¹ states that under similar conditions the white-fleshed varieties suffer more than yellow-fleshed, and soft-fleshed more than firm-fleshed varieties. This observation is in line with our results, since yellow and firm-fleshed varieties are usually classified as rutabagas and white and soft-fleshed ones as turnips, although these characters are not always constant and fairly resistant varieties of both seem to exist, contrary to the statements of Halsted¹¹ and Gilchrist,⁹ who found no varieties which showed marked immunity. Both Anderson¹ and Gilchrist⁹ found cabbages to be more resistant than turnips, though the latter states that in one of four seasons the reverse proved true. Ravn¹⁸ believes that the character of the soil influences the extent of infection, turnips proving more susceptible on sandy soil and cabbages more susceptible than turnips on clayey soil. The following table exhibits the result of 51 trials by Ravn on three soils.

Soil	Turnips more susceptible than cabbage	Cabbage more susceptible than turnip	Indeterminate
Clay	1	7	4
Sandy	15	6	7
Loam	4	1	6

Halsted¹¹ found differences between varieties, but concluded that no absolute immunity exists; a result concordant with those reported for cabbages (pages 77, 78), but discordant with those reported for turnips (page 82), for resistant varieties of turnips do seem to exist under conditions where cabbages and other crucifers are severely attacked.

3. TYPES OF HYPERTROPHY

The type of hypertrophy occurring with different crucifers has previously received little or no attention. It is important, however, since upon type and location depend largely the extent of the injury. The examination of many thousands of plants, including 28 genera and 104 species, leads the writer to stress the occurrence of definite types of hypertrophy more or less characteristic of certain crucifers. In many cases the group to which a given root belongs can be asserted by a study of the hypertrophy. There are, of course, intermediate types on various crucifers, but certain ones exist and merit recognition and description. Six types may be briefly described as follows:

1. *Brassica oleracea*: Complete clubbing of main and lateral roots.

2. *Sisymbrium altissimum*: Clubs on main root, laterals free.

3. *Sisymbrium officinale* and *Erysimum cheiranthoides*. Clubs on lateral roots, main root free.

4. *Lepidium sativum*: Clubs on main and lateral roots with club-free rootlets above the diseased portion.

5. *Raphanus sativus*: Clubs as tumors of the root.

6. *Raphanus sativus*: Dark, decomposing spots on the root.

1. The first type commonly occurs on *Brassica oleracea* and several other crucifers and is the form described in literature as characteristic of the disease. The whole root system may become enlarged and swollen in a more or less irregular, fusiform manner, strikingly resembling fingers and toes. Both the main and the lateral roots become involved in the hypertrophy, until in advanced stages there is no indication of active rootlets. The main root becomes clubbed and, as the laterals are formed, they, also, become diseased, until the whole root system becomes one large irregular tumor. This is the only type concerning which the term "finger and toe" can be considered a characteristic descriptive name. It is decidedly the most injurious type of clubbing.

2. The second type includes those where the hypertrophy is confined to the main root, the laterals being healthy. The main root may become infected at any point between the crown and the tips, causing an almost uniform swelling which completely encircles the root at that point. Should the main root branch into two or more secondary tap-roots, these may become infected, but their rootlets do not club. This is one of the most injurious forms of clubbing, particularly if the hy-

pertrophy is situated above all the free rootlets which assimilate plant food. This type is quite common on *Sisymbrium altissimum*.

3. The third type includes those where the hypertrophy is confined to the lateral roots, the main root being healthy. The swelling may be small and fusiform and scarcely visible on the smallest rootlets, or may consist of large knots several times the diameter of the main root. The large clubs on the lateral roots are characteristic of *Sisymbrium officinale*; the smaller clubs of the genera *Erysimum*. This type is never serious unless a large number of the rootlets become so clubbed as to interfere with the assimilation of plant food.

4. The fourth type includes those where the club is located on the main tap-root, at or just below the point where the leaves are attached. It resembles type 2. It is a very injurious form and often causes the early death of the plant. It is characteristic of *Sisymbrium altissimum* and *Lepidium sativum*.

5. The fifth type is characterized by lobulated enlargement of the tap-root, combined with the ordinary fusiform swelling of the rootlets. The club may or may not affect the root in its entire diameter, but often occurs as a tumor embedded in healthy tissue. This type is confined to the succulent roots such as radishes, *Raphanus sativus*, and turnips, *Brassica Rapa*, *B. campestris*.

6. The sixth type includes those where true hypertrophy does not exist, but the disease manifests itself as cracks or fissures in the tissue and as darkened areas which turn black and furnish starting points for the soft rots which sometimes follows. Appel and Werth² claim that this type of disease is characteristic of radishes. During our trials it was common only on the Everlasting radish, in addition to the ordinary fusiform swellings of the rootlets. No record of its occurrence on other varieties has been made although it has been observed.

While these six forms of hypertrophy are generally typical of the disease as it occurs on certain species and varieties, nevertheless they are apt to intermingle and at times two or more types may appear on the one plant. These types are remarkably constant, as constant as any type in the organic world.

4. PREVENTION BY SOIL TREATMENT

The prevention and control of club-root has been studied in many lands, yet the disease continues to spread to new localities and to become more abundant in old infected fields. This is due not to the lack of remedies but to the farmer's failure to apply them. The

efficacy of liming has been repeatedly shown by Halsted¹¹ and Jones¹² in America, by Massee,¹⁵ Gilchrist⁹ and Anderson¹ in England, and by Christensen,⁴ Appel² and Ravn¹⁸ in continental Europe. Halsted¹¹ in 6 years' trials found that 35 to 50 bushels of air-slaked lime per acre, applied preferably during the preceding season, prevents club-root in turnips and cabbages. Gas-lime, kainit, wood-ashes, copper sulphate, corrosive sublimate, salt, sulphur, calcium carbonate and sodium carbonate proved unsatisfactory. Jones¹² observed that 80 bushels of fresh stone lime, allowed to air-slake on the surface of the soil before plowing under, lessened the amount of clubbing and increased the crop by 60 percent. Christensen⁴ concluded that where the disease occurs or is likely to occur on acid soil, it should be combatted or its possible attack frustrated by heavy applications of marl or lime, and that when occurring on non-acid soils, thorough drainage and improved physical soil environment are advisable.*

A portion of the trial field at this Station was used in 1912 to test the value of various forms of lime as a preventive of the club-root of cabbage. It had been set with cabbages in 1911 and the crop was a complete failure because of club-root, scarcely a marketable head having formed. Two weeks before setting the young plants, the trial strip was divided into 9 plots, 45 feet long and 20 feet wide. Duplicate plots were treated with acre dosages of 150 bushels of air-slaked lime, 150 bushels of fresh stone lime, 650 pounds of calcium chlorid, two plots were left as control and one plot received an acre dosage of 100 bushels of air-slaked and 100 bushels of fresh un-slaked lime. The plots were so arranged as to minimize the effect of varying soil conditions. The plants were raised on club-root-free soil until they were 6 to 8 inches high, and transplanted in July in full length rows, the rows being 3 feet apart and the plants 12 to 15 inches apart in the row.

They received the usual cultivation, save that on August 15th 3 full rows on each plot were slightly hilled up, and, on September 1st, were hilled up until the soil completely covered the stalk and the cabbage head rested on the earth. Table XII exhibits the 1912 data, including the total number of heads per plot at the harvest, the total weight of the heads including all green leaves and the weight of solid saleable heads after all loose leaves have been removed, both on the plot and on the acre basis. The results of each duplicate plot are listed separately since soil divergencies doubtless affected the result.

*A more extensive review of the literature of various phases of soil treatment has been made and will be more fully discussed in a future publication.

The use of lime, particularly of air-slaked lime, was worth while in 1912. The double dosage of air-slaked lime and of fresh unslaked lime afforded the largest returns, several times as large as on the adjoining control plot. Almost as large a yield followed the use of 150 bushels of air-slaked lime. Fresh lime was less effective and calcium chlorid seemed of no value, or, perhaps, positively harmful. Clearly air-slaked lime proved the most satisfactory. A larger dosage might have done better, yet the results attained when 100 bushels air-slaked lime and 100 bushels of fresh unslaked lime were applied were not materially better than when 150 bushels of air-slaked lime were used.

TABLE XII. CABBAGE. EFFECT OF VARIOUS FORMS OF LIME AS PREVENTIVES OF CLUB-ROOT (1912)

Quantity and form used		Plants per plot	Total weight of heads	Total weight of saleable heads	Plants per acre	Total weight of heads per acre	Weight of saleable heads per acre
I.	150 bushels air-slaked.....	156	873.4	429.2	8,390	46,970	23,082
II.	150 bushels, fresh unslaked..	104	319.6	131.4	5,593	17,188	7,067
III.	650 pounds, calcium chlorid..	194	212.	450.	10,432	11,402	2,440
IV.	Control	55	58.	12.5	2,958	3,119	672
V.	150 bushels, air-slaked.....	137	620.2	330.3	7,368	33,353	17,748
VI.	150 bushels, fresh unslaked..	128	258.5	99.	6,884	13,902	5,324
VII.	Control	129	243.5	111.	6,938	13,095	5,970
VIII.	100 bushels, air-slaked and 100 bushels unslaked	133	752.5	483.2	7,153	40,470	25,986
IX.	650 pounds, calcium chlorid..	142	150.2	44.	7,636	8,078	2,366

The trials were repeated in 1913 in order to determine whether the effect of liming was noticeable from year to year, the 1912 plots being again set with cabbage plants without further additions of lime. The situation was identical in all respects with that of 1912, except that the soil had been under the influence of the lime for a year instead of for a few days before the plants were set. This doubtless resulted in a more thorough commingling of the lime with the soil.

Conditions other than those induced by the liming doubtless influenced the size and value of the crop. Thus the 1912 seasonal rainfall was greater than during the same period in 1913, as indicated on page 94. Hence conclusions must be limited by the terms of the controls of each year and cross comparisons are inapplicable. Table XIII shows the number of plants, total weights, numbers and total weights of saleable heads from the various plots for 1913, together

with their acre equivalents; and table XV shows the percentage of clubbing as influenced by the various treatments.

TABLE XIII. CABBAGE. EFFECT OF VARIOUS FORMS OF LIME AS PREVENTIVES OF CLUB-ROOT (1913)

Quantity and form used		Plants on plot	Total weight of heads	Number of saleable heads	Weight of saleable heads	Plants per acre	Weight of heads per acre	Number of saleable heads per acre	Weight of saleable heads per acre
I.	150 bushels, air-slaked.	132	1,140.8	123	653.3	4,260	36,830	4,085	21,060
II.	150 bushels, fresh unslaked	136	1,012.5	131	534.	4,390	32,640	4,355	17,210
III.	650 pounds of calcium chlorid	136	283.5	92	78.5	4,390	9,123	2,966	2,534
IV.	Control	63	143.5	51	55.5	2,034	4,632.	1,644	1,789
V.	150 bushels, air-slaked.	133	1,020.5	?	568.5	4,290	32,940	?	18,325
VI.	150 bushels, fresh unslaked	129	739.3	124	431.	4,163	23,840	4,124	13,900
VII.	Control	128	574.3	125	329.5	4,131	18,495	4,156	10,630
VIII.	100 bushels, air-slaked and 100 bushels fresh unslaked, per acre..	130	1,143.8	127	711.3	4,190	36,930	4,221	22,940
IX.	650 pounds, calcium chlorid	124	583.	114	291.	4,000	18,793	3,789	9,670

The yields on plots 1, 5 and 8 (air-slaked lime) were greater in 1912 than in 1913, but on the plots receiving fresh lime, calcium chlorid and on the controls, the 1913 crop was the larger than on the same areas in 1912. As a whole, however, the 1912 findings were confirmed. The plot to which 200 bushels of air-slaked and of fresh unslaked lime were applied yielded 22,940 pounds; those to which 150 bushels of air-slaked lime were applied yielded 19,700 pounds; those to which 150 bushels of fresh lime were applied, 15,500 pounds. The calcium chlorid plot yields resembled those obtained on the control plots.

Table XIV condenses the data of the two seasons.

TABLE XIV. CABBAGE. AVERAGE ACRE YIELDS ON LIMED PLOTS

Soil treatment in 1912	1912		1913	
	Total weight of heads	Weight of saleable heads	Total weight of heads	Weight of saleable heads
150 bushels, air-slaked	40,162	20,415	34,935	19,693
150 bushels, fresh unslaked....	15,540	6,195	28,240	15,555
100 bushels, air-slaked	40,470	25,986	36,930	22,940
100 bushels, fresh unslaked....				
150 bushels, calcium chlorid....	9,790	2,402	13,958	6,102
Control	8,107	3,321	11,564	6,210

TABLE XV. CABBAGE. EFFECT OF VARIOUS FORMS OF LIME AS PREVENTIVES OF CLUB-ROOT (1913) STATED AS PERCENTAGES

Quantity per acre and form used on soil before setting	Number of plants on plot	Number not clubbed	Number clubbed	Number badly clubbed	Number slightly clubbed	Percentage not clubbed per acre	Percentage clubbed per acre	Percentage badly clubbed per acre	Percentage slightly clubbed per acre
150 bushels of air-slaked lime.....	132	52	80	57	23	39.4	60.6	43.1	17.5
150 bushels of fresh unslaked lime.	136	5	131	102	29	3.7	96.3	75.	21.3
650 pounds of calcium chlorid.....	136	0	136	127	9	0	100.	93.4	6.6
Control	63	0	63	63	0	0	100.	100.	0
150 bushels of air-slaked lime.....	133	20	113	84	29	15.	85.	63.1	21.9
150 bushels of fresh unslaked lime.	129	12	117	106	11	9.3	90.7	82.2	8.5
Control	128	3	125	122	3	2.3	97.7	95.4	2.3
100 bushels of air-slaked and 100 bushels of fresh unslaked lime	130	57	73	50	23	43.8	56.2	38.4	17.8
650 pounds of calcium chlorid.....	124	0	124	124	0	0	100.	100.	0

Table XV, which expresses the results as percentages, clearly sets forth the effects of liming on clubbing. Where either air-slaked or fresh lime was used the disease percentage was lowered as compared with that observed on the control or calcium chlorid plots. Where air-slaked lime was used, 61 and 85 percent of the crops were clubbed, as against 99 percent on the controls. Where fresh unslaked lime was used 96 and 91 percents as compared with 99 percent, a less favorable showing. Where 100 bushels each of fresh and air-slaked lime were used, but 56 percent were clubbed as compared with 98 percent on the control. Calcium chlorid was without effect.

Furthermore, and important, such clubbing as occurred on the limed areas was often confined to the lower roots, at least there were many free rootlets above the diseased ones. On the other hand, the clubbing on the calcium chlorid and control plots usually extended to the surface of the ground, few healthy rootlets existing above the diseased parts. Hence a larger proportion of the crop on the limed areas was but slightly clubbed and, therefore, able to form saleable heads. Apparently the location of the club depends largely on the location of the lime. This for the most part seemed to lie in the upper soil layers, not readily penetrating lower down unless worked into the soil when applied. Further work is contemplated looking towards the correlation of the location of the club with the distribution of the lime, yet it already seems safe to hazard the statement that clubbing is effectively prevented only to the depth that the lime penetrates, which would

indicate that the lime should be thoroughly incorporated with the soil to a depth of 6 to 9 inches.

5. "HILLING UP" AS A MEANS OF AIDING PLANTS TO RESIST DISEASE ATTACKS

It is the experience of Mr. H. S. Merrihew, the veteran market gardener on whose premises this work was carried out, that if the soil is thrown in around the cabbage during cultivation in such a manner that the stalk is banked up, the yields seem greater, due apparently to the increased activity of the adventitious roots which develop as a result of this procedure on the stalk above the older and diseased roots. In order to determine the facts, the cabbage plants in 3 rows on each limed plot (page 87) were slightly hilled on August 15th, 1912, the soil being thrown in around the stalks; two weeks later it was yet further thrown up until the heads rested on the soil and the stalks were completely surrounded. The plants on 3 similar rows of each plot were left unhilled as a control. The adventitious roots formed as a result of this practice on the stem above the diseased root are relatively disease free and function in the place of the affected roots which are practically useless. Roots located below a club are of little value, since the nourishment they absorb is retained by the club and does not reach the head. Any procedure which induces club-free roots to form above the diseased roots greatly lessens the damage caused by the club. Plate IV shows the roots of hilled and unhilled plants. Very few club-free rootlets appear above the club on the main root in the one case, while in the other an abundance of healthy rootlets appear above the clubs. The one could not produce a saleable head, the other should yield a large and normal head.

This trial was repeated in 1913. The hilling process was begun in early August rather than mid-August, it being thought that greater benefits might accrue. The first hilling was slight, but two weeks later the soil was thoroughly worked in around the stalks. However, the climatic conditions of August, 1913 were quite unlike those obtaining during the previous August, which possibly explains the unlikenesses of the results obtained one year as compared with another. The results appear in tables XVI and XVII which show the numbers of plants on each plot at harvest, the total weights of the heads including all green leaves, the total number of saleable heads, and the total weight of saleable heads, on both the plot and the acre basis.

TABLE XVI. CABBAGE. EFFECT OF HILLING DISEASED PLANTS (1912)

Soil treatment per acre	Cultural treatment	Number of plants	Total weight of plants	Weight of saleable heads	Number of plants per acre	Total weight of plants per acre	Weight of saleable heads per acre
			lbs.	lbs.		lbs.	lbs.
150 bushels air-slaked lime	Hilled	86	489	262	5,547	31,547	16,944
	Not hilled	70	384	166	4,515	24,787	10,739
150 bushels fresh unslaked lime.....	Hilled	60	198	88	3,870	12,771	5,676
	Not hilled	44	121	43	2,838	7,843	2,799
650 pounds calcium chlorid	Hilled	88	167	45	5,676	10,772	2,903
	Not hilled	106	35	0	6,837	2,258	0
Control	Hilled	29	39	11	1,871	2,548	742
	Not hilled	26	18	1	1,677	1,193	65
150 bushels air-slaked lime	Hilled	65	313	174	4,193	20,221	10,875
	Not hilled	72	307	156	4,644	19,802	10,062
150 bushels fresh unslaked lime.....	Hilled	60	113	51	3,870	7,321	3,322
	Not hilled	68	135	47	4,386	8,708	3,057
Control	Hilled	63	129	63	4,064	8,321	4,096
	Not hilled	66	114	47	4,267	7,383	3,064
100 bushels air-slaked, 100 bushels fresh unslaked lime.....	Hilled	66	410	258	4,267	26,477	16,654
	Not hilled	67	342	225	4,322	22,059	14,513
650 pounds calcium chlorid	Hilled	70	82	29	4,515	5,302	1,871
	Not hilled	72	68	15	4,644	4,386	968

TABLE XVII. CABBAGE. EFFECT OF HILLING DISEASED PLANTS (1913).

Soil treatment per acre	Cultural treatment	Number of plants	Total weight of plants	Weight of saleable heads	Number of plants per acre	Total weight per acre	Number of saleable heads per acre	Weight of saleable heads per acre
150 bushels air-slaked lime.....	Hilled	66	543	310	4,257	35,023	3,870	20,027
	Not hilled	66	597	343	4,257	38,554	4,063	22,133
150 bushels fresh unslaked lime	Hilled	69	465	192	4,450	30,024	4,515	12,384
	Not hilled	67	547	352	4,321	35,201	3,934	20,904
650 pounds calcium chlorid	Hilled	69	158	35	4,450	10,191	3,160	2,289
	Not hilled	67	125	43	4,321	8,034	2,773	2,773
Control	Hilled	32	76	28	2,064	4,902	1,806	1,804
	Not hilled	31	67	27	1,999	4,353	1,483	1,773
150 bushels air-slaked lime	Hilled	70	440	236	4,515	28,412	4,515	15,223
	Not hilled	63	580	322	4,063	37,410	5,031	21,807
150 bushels fresh unslaked lime	Hilled	66	321	183	4,257	20,736	3,676	11,807
	Not hilled	63	417	248	4,063	26,944	4,321	16,000
Control	Hilled	67	283	158	4,321	18,253	3,934	10,223
	Not hilled	61	291	171	3,934	18,785	4,128	11,023
100 bushels air-slaked, 100 bushels fresh unslaked lime	Hilled	63	550	349	4,386	35,475	4,321	22,555
	Not hilled	62	593	361	3,999	38,296	3,870	23,310
650 pounds calcium chlorid	Hilled	66	261	148	4,257	16,834	3,741	9,544
	Not hilled	58	322	143	3,741	20,769	3,612	9,223

A striking variation is manifest in the outcome of the two seasons' work. Decidedly beneficial results were secured in 1912, but in 1913 a decided injury was done. A gain was registered on every one of the 9 hilled plots in 1912, and where the clubbing was the most severe (calcium chlorid and control plots) the benefit was most marked; indeed, it was a startling gain in some cases. Yet the 1913 results are utterly at variance therewith, 3 plots showing no result one way or the other and 6 more or less decided results in the opposite direction. To be sure the 1913 injury resulting from hilling was less in actual weight of saleable cabbage than the 1912 benefits derived from the same practice; furthermore, on the two 1913 plots whereon hilling did result in some slight increase in yield the clubbing was quite severe, which is in line with the conclusion that hilling is most likely to prove helpful when the disease is most severe.

Notwithstanding the fact that hilling apparently sometimes tends materially to increase the yield, at no time was the increase attributable solely to this practice large enough to make a success of a badly diseased crop. Thus in 1912 one unhilled plot was a complete failure, while its hilled companion carried only 2,900 pounds per acre, worth perhaps \$29.

The hilling practice in 1913 did not greatly encourage the formation of adventitious roots, notwithstanding the fact that they were hilled earlier and more thoroughly than in 1912. This was doubtless due to untoward climatic conditions, especially to relative lack of rain. The soil around the stalks was so dry that the growth of the rootlets was checked. Furthermore, the hilling removed the loose soil mulch from between the rows, thus stripping and injuring the original roots and encouraging the evaporation of soil moisture. The local weather bureau records (appended) show that the 1913 seasonal rainfall was but two-thirds that of 1912, the July and August precipitation in 1913 but two-thirds that of 1912, and that it was well below normality. Not only was the 1912 seasonal rainfall greater in total volume but it was more uniformly distributed throughout the growing season, as indicated by the number of days on which .01 inch or more of rain fell; and the cloudiness in 1912 was somewhat greater than in 1913. These facts, greater rainfall, its more even distribution and cloudy weather, undoubtedly favored the formation of adventitious roots in 1912, while the hilling-up process aggravated the influence of the dry weather during 1913 and hindered the formation of new rootlets.

TABLE XVIII. PRECIPITATION, JULY, AUGUST, SEPTEMBER AND OCTOBER, 1912 AND 1913—(WEATHER BUREAU, BURLINGTON)

	Precipitation in inches			Number of clear days	Number of partially cloudy days	Cloudy days	Average cloudiness, tenths
	Total	Departure from normal	Number of days with .01' or more				
1912 July	3.24	—0.5	12	12	10	9	4.9
August	2.55	—1.5	15	3	11	17	7.0
September	5.26	+1.9	19	5	9	16	7.1
October	2.95	—2.	13	8	13	10	5.4
Total	14.	—2.1	59	28	43	52	6.1*
1913 July	2.83	—1.0	14	5	13	13	6.0
August	1.10	—2.9	8	10	14	7	5.3
September	2.66	—0.7	6	10	12	8	5.0
October	2.90	—0.3	18	4	8	19	7.5
Total	9.49	—4.9	46	29	47	47	5.95*

*Average for the four months.

SUMMARY.

Observations on the susceptibility of crucifers to club-root indicates that the great majority of, if not all, crucifers are susceptible. A few varieties were not infected on our plots. The range varies all the way from 100 percent susceptible to 100 percent immune.

Cabbages show variety resistance to the attack of club-root as revealed: (1) by the percentage clubbed, (2) by the number of saleable heads, and (3) by the weight of saleable heads per acre. Among the more susceptible varieties of cabbages are Mammoth Rock Red, Dark Red Erfurt, American Savoy, Perfection Savoy, All Seasons and Volga, while among the more resistant varieties may be included Hollander, Stone Mason, Large Late Flat Dutch and Henderson's Early Summer. No variety escaped, indeed none showed more than 26 percent of healthy plants. Mammoth Rock Red and Perfection Savoy were the worst clubbed, and Hollander the least clubbed.

Radishes show a wide range of susceptibility to club-root, varying from the Long Scarlet Radish (92.2 percent clubbed) to the Giant Stuttgart (5.6 percent clubbed). No variety was completely free from infection. The disease appears on the radish in addition to the common form as dark discolored spots and fissures.

The range of susceptibility among the turnips (*Brassica Rapa*) and rutabagas (*Brassica campestris*) is even greater than among the

cabbages or radishes, varying from Southern Curled Turnip (100 per cent clubbed) to White Swede, Sweet Russian, and Sweet German free from clubbing. Many varieties are fairly resistant. The soft, white-fleshed turnips seem to suffer more than the firm, yellow-fleshed rutabagas.

The wide range of susceptibility among the species and varieties offers a hope that among the cabbages, turnips, radishes and the more generally cultivated crucifers there may be some varieties which will prove still more resistant to the parasite than are the ones commonly cultivated.

The examination of many thousands of plants, including 28 genera and 104 species, leads the writer to describe 6 types of hypertrophy, which are more or less characteristic of certain crucifers.

The application of lime, preferably air-slaked lime, at the rate of 150 bushels per acre induced a yield of 23,082 pounds of cabbage as compared with one of 672 pounds per acre where no lime was applied; and an almost equally pronounced result was attained the next year on the same plots. Lime to be effective must be thoroughly worked into the soil to a depth of 6 to 9 inches or more, as it does not otherwise readily penetrate the soil.

Hilling-up cabbage stalks caused the formation of adventitious roots above the diseased roots and materially increased the crop in 1912. No such beneficial result were attained in 1913, indeed, damage was done, possibly because of the lack of rain. The 1912 yield on some hilled plots was increased more than tenfold. Neither excessive hilling nor hilling during drought is advisable.

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FEBRUARY, 1915

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FARM APPLE STORAGE

BY M. B. CUMMINGS AND P. M. LOMBARD¹

SUMMARY

A study of apple storage practice in Vermont indicates that there is need of much improvement. More attention may properly be given to the preservation of a crop after it is produced. It is often as important to preserve well as to produce well.

Trials have been conducted to ascertain the value of different mechanical media in preserving apples. Mill sawdust, cork sawdust, leaves, chopped hay, paper wrappers and sand have been used. Shrinkage and decay losses have been determined and estimates made as to appearance and flavor. Only the mill sawdust and cork sawdust seem to possess value. All the media kept the apples cooler than when no media were used; but shrinkage, decay and flavor impairment were more fatal than the thermometer. Mill sawdust from resinous woods imparts an undesirable flavor to apples, but hardwood sawdust does not injure their flavor.

Four kinds of protective dips were employed to determine their influence on the preservation of apples, copper sulphate, bordeaux mixture, lime-water, and paraffin being used as immersion fluids preliminary to storage. Bordeaux was most effective in retarding decay and preserving the flavor.

Apples keep best by first immersing them in bordeaux and then packing them in hardwood sawdust, yet apples that are merely dipped in bordeaux, keep nearly as long as those thus treated, and subsequently packed in sawdust, and their flavor is if anything the better.

The structure of the flesh and skin of an apple have much to do with its keeping qualities. The best keeping varieties have a firm flesh, compact tissue and a thick and highly impervious skin. The suberization and cutinization of the cuticle is a protective contrivance which is of value in prolonging the life of apples.

¹The authors wish to acknowledge their indebtedness to J. W. Wellington and R. P. Armstrong, former assistant horticulturists, and W. C. Stone, the present assistant horticulturist, who gave material assistance in the conduct of this work.

INTRODUCTION

Most New England farmers place a few barrels of winter apples in their cellars, storing more or less according to the size of the family and to the abundance of the crop. They expect that some will spoil and look upon such a loss as inevitable. They know that artificial cold storage would check this loss, but realize how impossible it would be to install so costly a system for such a purpose. The principles and practice of apple cold storage on a commercial scale are well established; but thoroughly successful apple keeping on a small scale in New England farm cellars is the exception rather than the rule. It seemed, on this account, worth while to study apple storage conditions on the farm, to determine local practice touching this matter, to try different mechanical media for packing, to use fungicides on the fruit with a view of warding off fungus attacks and, finally, to attempt to discover the fundamental reasons why some varieties keep better than others.

The work outlined in this bulletin, therefore, naturally divides itself into three parts:

- I. Apple storage practice in Vermont.
- II. Studies in apple storage on a small scale.
- III. The relation of skin and cell structure to the keeping qualities of the apple.

I. APPLE STORAGE PRACTICE IN VERMONT

With a view of finding out the extent of apple storage in Vermont, the varieties stored, and particularly the methods and materials used in storage, several circular letters were sent to Vermont orchardists. A considerable number of answers were received from correspondents so widely scattered that they may be safely held to represent the State as a whole; furthermore, visitation has supplemented letter writing; and, finally, the senior author has had unusual facilities in this connection because of his intimate contact and large acquaintance with the members of the State Horticultural Society.

The first outstanding fact in this survey relates to the extent of storage. Vermonters are not extensive storers of apples. There are very few commercial storehouses, the large growers usually shipping their apples at harvest time or shortly thereafter. The produc-



EFFECT OF SAWDUST ON PRESERVATION.

Above, Baldwins from dry sawdust; in middle, R. I. Greenings from dry sawdust; below, R. I. Greenings from damp sawdust.



Above, Baldwins from damp sawdust; in middle, Roxbury Russet, at left undipped, at right dipped in paraffin; below, Baldwin, Northern Spy and R. I. Greenings, showing ill effect of damp media.

tion side of Vermont's apple business is far in advance of its storing and marketing aspects. Among the smaller growers and those who possess merely a family orchard, the amount of apples put aside for winter use is governed less by family needs than by seasonal conditions and the abundance of the crop. In this connection it may be suggested that farmers have a splendid opportunity to lower the "high cost of living" by giving more attention to the winter apple supply. A scant supply for a long period is to be preferred to an overabundance for a short time.

Again, it was found that the number of varieties put in storage is too small for the most satisfactory and long-term supply. To be sure too many kinds of apples are now being grown in Vermont, and many of them are perishable sorts, and, consequently, there is too little variety for winter uses. Some readjustment should serve a useful purpose.

Few Vermont orchardists have separate storage houses and a yet smaller number separate storage rooms or chambers. Most of them store their apples in the house cellar. Only a few use any kind of media in storing apples. Two correspondents find paper wrappers successful, one declares sawdust to be a failure, and four deem soil, usually sand, the best medium. One correspondent reports preservation only to March, 7 until spring, 5 to April, 10 to May, 4 to June, while 11 keep apples until July or even until the fall harvest comes again.

II. STUDIES IN APPLE STORAGE ON A SMALL SCALE

PREVIOUS WORK ON COLD STORAGE OF APPLES

It is not the purpose of this bulletin exhaustively to review previous publications on cold storage of apples; yet it may be well to note in passing some of the most important points in connection with the development of our knowledge relating to this subject. Powell¹ was among the early workers along this line. He pointed out the fact that low temperatures retard ripening and, consequently, retard decay. He also marked the prevalence of scald, producing a browning and russetting of the fruit, and attributed the malady to an enzym which is apt to develop rapidly on fruit which is prematurely picked. Gore² reported that warmth favored chemical change and consequent deterioration.

1. U. S. Dept. Agr., Bu. Pl. Ind., Bul. 40 (1903).

2. U. S. Dept. Agr., Bu. Chem., Bul. 94 (1905).

Morse³ called attention to the fact that at summer temperatures apples undergo respiratory metabolism from 4 to 6 times as rapidly as in modern cold storage. Lamson⁴ found that wrapping apples in paper was an advantageous procedure, provided they were to be kept until spring, and further stated that the kind of wrapper used was immaterial, provided it was clean and carefully put on the fruit. Beach⁵ cited the remarkable differences as between varieties in relation to their storage values and queried as to the wisdom of trying to store summer apples save when winter varieties are unusually scarce. Beach and Clark⁶ have made a very useful contribution to apple storage literature in regard to the natural season of ripening and keeping of New York varieties, thus enabling the farmer so to distribute his choice of varieties as to provide a continuous supply for family use. Eustace⁷ finds that but one of the several species of mold concerned in the decay of fruits—*Penicillium glaucum*—is active at cold storage temperatures. Corbett⁸ made careful tests of West Virginia apples and demonstrated the value of closed receptacles and of a certain degree of humidity in long preservation. It is not quite certain to whom should be accorded credit for proving that mechanically injured fruits decay quickly whatever the conditions of storage. Nearly all writers note this fact. Powell,⁹ however, was among the first to give it general publicity. The character of the soil, the age of the trees, the care given the orchard, the local climate and the character of the season are said by Powell to influence the keeping qualities of fruit, as shown in comparative tests of varieties from different sections of the country when subjected to the same storage conditions.

Otto¹⁰ studied the chemical changes in apples and found constant increase in the specific gravity and in the acid, sugar and extract contents following storage. Crump and Bunyard¹¹ pointed out the necessity of and indicated a desirable mode of underground cellar storage for apples in England. Ruddick¹² established the advantages of cold storage for winter and spring shipments to foreign markets and proved that cold storage after picking while life processes are still active is more important than for the same length of time at some later stage in

3. Jour. Am. Chem. Soc., 30, p. 876 (1908).

4. N. H. Sta., Bul. 93 (1902).

5. Iowa Sta., Buls. 72 (1903), 108 (1909).

6. N. Y. (State) Sta., Bul. 248 (1904).

7. N. Y. (State) Sta., Bul. 297 (1908).

8. W. Va. Sta., Bul. 74 (1901).

9. U. S. Dept. Agr., Bu. Pl. Ind., Bul. 48 (1905).

10. Gartenflora, 50, No. 12 (1901).

11. Garden, 59, No. 1534 (1901).

12. Can. Dept. Agr., Dal. and Cold Stor. Div., No. 24 (1910).

the life of the apple. Greene¹³ stored frozen apples and reported that they can be held in safety if not too severely frozen, that is to say if not subjected to a temperature lower than 20° F. and if favorable weather followed, thus allowing the fruit to thaw out gradually. He also found that small apples keep better than large ones. Lewis¹⁴ determined the possibilities of home storage by the use of an out-door cellar, and found that in Kansas apples could be successfully preserved until the first of March. It is interesting to note in this connection that a few Vermont orchardists have been practicing cave storage for upwards of a dozen years.

This brief review shows that, although several investigations of apple storage have been made and the publications are somewhat voluminous, nothing has been reported, so far as the writers could determine by a somewhat careful search of literature, relating to the use of media, the influence of fungicidal immersion, or the relation of the structure of the skin and flesh to the keeping qualities of the fruit.

EXPERIMENTAL DETAILS

The orchard. It is a matter of common knowledge that climate, soil and cultural conditions influence the keeping qualities as well as the eating qualities of an apple. In order to minimize these differences, the apples used in the trials now under discussion were taken each year save the last from a single orchard, situated on a limestone formation and a clay loam soil near Lake Champlain in Grand Isle county. The Baldwins, Northern Spys and Rhode Island Greenings used were grown on trees 28 years old, which were in fair condition having been regularly sprayed but not well pruned. The land had been but sparingly fertilized, occasionally tilled and frequently pastured to sheep. These conditions were considered fairly representative of those which prevail in many sections of Vermont. The fruit used in the 1913-14 trials grew in a Chittenden county orchard.

The storage room. A basement room, resembling in many respects a farmhouse cellar, was used. Ventilation was secured and temperature controlled by means of a cellar window which opened at the surface of the ground. The fruit was placed therein as soon as it was received each fall: on Nov. 5 in 1909; Nov. 20 in 1910; Dec. 11 in 1911 and Nov. 10-11 in 1913. Much care was taken to secure samples of uniform grade in preparing the fruit for storage and in select-

13. Iowa Sta., Bul. 144 (1913).

14. Fruit Grower and Farmer, Oct., 1913.

ing when comparisons between different media or the same media under different conditions were instituted.

The experimental fruit was examined once a month throughout the course of the tests during the first three seasons, the decayed specimens being weighed, recorded and discarded. The relative conditions of the several lots was judged by comparison with checks. All discarded fruit was sampled with a view of determining the effect of the media and the treatment upon the flavor. Daily temperature readings of the storage room were taken in 1910-11, 1911-12 and 1913-14 and media records were made at least every other day.

Two distinct lines of treatment were instituted, viz., protective dips or washes and mechanical media in packing. In the one case fungicides and paraffin were used, in the other sawdust of various kinds, leaves, chopped hay, sand and paper wrapping. In all cases untreated parallel check lots were handled for purposes of comparison and control.

The lots used in the trials of the first three years' list as follows:

1. Protective dips:
 - (a) Bordeaux mixture.
 - (b) Copper sulphate.
 - (c) Lime water.
 - (d) Paraffin.
2. Mechanical media:
 - (a) Cork sawdust, dry.
 - (b) Sawdust, dry, damp, soft and hardwood.
 - (c) Leaves, dry, damp.
 - (d) Sand, damp, dry.
 - (e) Chopped hay.
 - (f) Paper wrappers.
 - (g) Sawdust after bordeaux mixture.

1. PROTECTIVE DIPS

(a) BORDEAUX MIXTURE

Trials were conducted each year with various dips to determine if possible their service in checking decay. Bordeaux mixture, a prominent and well known fungicide, was naturally chosen as a fungicidal dip, being made according to the formula, 4 pounds of copper sulphate, 4 pounds of lime and 50 gallons of water, the strength commonly employed in orchard spraying. It was hoped that by dipping the apples in bordeaux one might rid them of their fungus enemies. The first year the apples were dipped directly in the bordeaux and im-

mediately packed in open boxes, unwrapped. They were kept 3 months with results as follows:

TABLE 1. BORDEAUX MIXTURE, KEPT THREE MONTHS

	Shrinkage		Decay	
	Treated	Untreated	Treated	Untreated
Baldwin	7.6	9.4	3.4	5.
Northern Spy	7.8	9.4	31.2	17.5
Rhode Island Greening	5.9	10.6	28.1	3.1

In the next season's trials of 4 months, the Baldwins shrunk somewhat, but with no decay loss; the Northern Spys did not shrink, but decay loss exceeded 42 percent, the Rhode Island Greenings did not shrink and the decay loss was but 6 percent.

A similar trial was conducted, differing only in the fact that the fruit was wrapped in Oregon apple paper before dipping. There was apparently no advantage secured by wrapping.

The third season's work with bordeaux differed from previous trials in that a solution $2\frac{1}{2}$ times as strong as in earlier trials (10 pounds each of copper sulphate and lime to 50 gallons of water) was used and that the fruit was wrapped in single paraffin paper after dipping.

TABLE 2. BORDEAUX AND PARAFFIN PAPER, 1911-12

	Original weight in ounces	First month			Second month			Third month			Fourth month		
		First weight, ounces	Number decayed	Second weight, ounces	First weight	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces
Baldwin	103.8	102.3	2	93.3	75.5	1	72.	70.8	0	70.8	69.5	0	69.5
Northern Spy	65.3	64.3	0	64.3	57.	1	51.5	51.	0	51.	50.3	0	50.3
Rhode Island Greening ...	86.	84.5	0	84.5	83.3	0	83.3	82.3	0	82.3	81.	0	81.
CHECK DATA, 1911-1912													
Baldwin	129.5	125.5	0	125.5	122.3	3	107.	104.8	4	85.8	84.5	1	79.
Northern Spy	130.8	128.8	0	128.8	125.5	2	116.3	114.8	1	109.5	107.5	2	98.5
Rhode Island Greening ...	114.5	110.5	0	110.5	107.3	2	98.3	96.3	1	92.5	90.	3	76.

	Shrinkage				Decay			
	Treated Ounces	Percent	Untreated Ounces	Percent	Treated Ounces	Percent	Untreated Ounces	Percent
Baldwin	21.8	21.	10.8	8.3	12.5	12.1	39.8	30.7
Northern Spy	9.5	14.6	8.8	6.7	5.5	8.4	23.5	18.
Rhode Island Greening.	5.	5.8	11.8	10.3	0	0	26.8	23.4

The treated Baldwins and Northern Spys shrank more than did the checks and the Rhode Island Greenings 4.5 percent less; but the decay losses were decidedly lessened by the treatment, in the Baldwins by 18.6 percent, in the Northern Spys by 9.6 percent, and in the Rhode Island Greenings by 23.4 percent. At the close of the trial the flavor of the treated specimens of all three varieties was pronounced superfine by no less than 20 different individuals, none of whom knew anything of the nature of the treatment, or, indeed, with certainty that the apples had been treated at all. The influence on flavor was so marked and unexpected that this aspect of the subject was given further consideration in the succeeding season.

Influence of bordeaux on flavor. As has just been indicated, the 1911 Northern Spys, Rhode Island Greenings and Baldwins which had been dipped in strong bordeaux mixture retained an excellent flavor at the close of the trial. Fifteen plates of fruit, each representing a different storage treatment, were sampled for flavor by 20 members of the station staff. Each plate was numbered and no one knew which was which until the sampling was over and the individual verdicts were registered. The fruit dipped in bordeaux was pronounced by every one to be excellent in flavor and far superior to the other samples.

Further to test this point the writer conducted bordeaux trials on a larger scale during the winter of 1912-13. Apples were dipped in bordeaux mixture of strengths ranging from 5-5-50 to 15-15-50; in copper sulphate of strengths 5-50, 10-50, 15-50; in lime of strengths 5-50, 10-50, 15-50. Rhode Island Greening, Sutton Beauty, Ben Davis and Bismarck were used. The fruit was picked with great care in the station orchard and treated in the storage room. The specimens remained in the fungicidal solutions for 10 minutes, and, after removal, they were allowed to dry, and were wrapped in paper and placed in clean boxes. The fruit was sampled and the flavor judged at stated intervals throughout the winter. With but few and unimportant exceptions the samplers gave consistent opinions which may be epitomized as follows: The apples treated with bordeaux were much the best flavored specimens. Contrary to expectation it was impossible to distinguish the quality of flavor between the specimens which were dipped in 5-5-50 and those immersed in 15-15-50, or any of the intermediate strengths. Scarcely a demerit mark was registered against the apples thus treated until nearly the end of the season for the variety. Ben Davis, however, was an exception, for this variety when

treated like the others seemed no better in flavor or quality than untreated specimens.

The results thus attained were again confirmed in the winter of 1913-14 when entire barrels of apples were under trial. In this instance the varieties used were Rhode Island Greening, Northern Spy and Baldwin. One barrel of each of these varieties was either immersed in bordeaux, packed in sawdust, dipped in bordeaux and packed in sawdust or left untreated. Flavor tests were made at three periods throughout the winter, and in every instance the flavor of the apples that were given the bordeaux treatment preparatory to storage was much better than that of the untreated apples or those that were otherwise treated. The concordant results of the three seasons, and especially those attained under conditions of the storage of barrel lots, satisfy the writers of the correctness of the early inference as to the beneficial effect of bordeaux immersion as a means of preserving the flavor of apples in storage.

It is not within the province of this bulletin to explain or exhaustively to attempt to analyze the reasons why these solutions or mixtures influence flavor. However, one may hazard the assumption that the adhesive nature of bordeaux may tend to hinder the escape of the volatile oils which are believed to be associated with the flavor in fruit. It is, therefore, suggested in this connection that a film of disinfectant solution may assist in the retention of those attributes which are associated with flavor.

Disinfecting bruised fruit. In another connection mention may be made of the influence of bordeaux on fruit which has been mechanically injured. Its well known usefulness in the combat against saprophytic and parasitic pathogens has suggested its possible value in retarding the decay of injured apples. On October 18, 1912, 8 lots of Rhode Island Greenings, each containing 25 uniform specimens, were selected for observation on the retardation of decay. Those in series 1, 3, 5 and 7 were slightly jammed, whereas the epidermis of the apples in series 2, 4, 6 and 8 was conspicuously broken. There were then under observation fruits of two degrees of injury. Each series was then divided into two groups, controls and dips, the latter being immersed for 10 minutes in a 5-5-50 bordeaux mixture. This trial extended over a period of 5½ months, or until the fruits were passing into soft rottenness. A comparison of the control and treated lots showed that the disinfecting process availed but little, the latter decaying almost as rapidly as the former. There appears to be no way

of making amends through the use of protective immersions for bruising. Fruits once injured are sure to pass quickly regardless of treatment.

(b) COPPER SULPHATE

In view of the results obtained with the use of bordeaux, which is a combination of copper sulphate and lime, it seemed worth while to test the influence of copper sulphate alone. In this trial it was used at the rate of 5 pounds to 50 gallons of water. In the 3 months' trial of the first year, shrinkage and decay losses were as follows:

TABLE 3. COPPER SULPHATE, KEPT THREE MONTHS

	Shrinkage percentages Treated	Shrinkage percentages Untreated	Decay percentages Treated	Decay percentages Untreated
Baldwin	15.3	9.4	9.7	5.0
Northern Spy	19.6	9.4	10.9	17.5
Rhode Island Greening.....	24.2	10.6	9.9	3.1

The shrinkage and decay losses of the treated fruit—except the decay loss of Northern Spys—were greater than that of the untreated fruit. Repeated trials in succeeding seasons afforded similar results and forced the conclusion that dipping in copper sulphate as such is of no value as protection against shrinkage or decay in storage.

Copper sulphate solutions were also used with reference to their influence on flavor. After repeated trials it was found that these immersions gave good results. This fact was not brought out clearly in the earlier trials, but became evident under careful tests in comparison with bordeaux and lime treatments wherein special attention was given to considerations of flavor retention. A copper sulphate solution of a strength greater than 5 pounds in 50 gallons of water was not harmful in this respect, but exerted no better influence on flavor retention than did the weaker ones. The outcome, however, was slightly inferior to that attained by the use of bordeaux as detailed on page —.

(c) LIME WATER

Immersions of apples in lime water were made merely with reference to the influence of such dips on the relation to flavor. Several strengths were tried, ranging from 5 to 15 pounds in 50 gallons of water. The lime was slaked as for a bordeaux stock solution, and dilutions made as desired. The apples were submerged for 10 minutes, and, as soon as they became dry, were placed in boxes and set aside

for flavor tests. These were made at three different periods throughout the winter, 20 different people rendering opinions. Their composite judgment was that the apples immersed in lime water were slightly inferior in quality and flavor to those receiving the copper sulphate treatment and but little better than the checks.

(d) PARAFFIN

The quite general use of paraffin in sealing glass jars of preserved fruits suggested its possible utilization in the preservation of apples by dipping. Being colorless, odorless and non-porous, it seemed theoretically well fitted to preserve flavor and either to inhibit or retard shrinkage.

A paraffin of low melting point was used and warmed just enough to make it liquid. The apples were submerged for a minute, cooled, and placed in a cool cellar. Check specimens were carefully selected and accorded the same storage room conditions.

Preliminary trials were made with Roxbury Russets. After 3 months' storage, the coated and uncoated fruit were compared with results favorable to the former. The apples thus treated were as plump, crisp and juicy as on the day when they were picked, while the undipped fruit was considerably shrivelled and tasted somewhat dry. Furthermore the check lot lost in weight, whereas the dipped apples were scarcely lighter than at the beginning of the test.

In view of this promising outcome, more extensive trials were made in 1913-14, using Fameuse, Jonathan, Baldwin, Ben Davis and Roxbury Russet. Some of the varieties were kept in a drawer at office room temperatures; others were placed in a basement room in a cool temperature. Since it was impossible at the late date of starting the trials with Roxbury Russet to get perfect specimens, these apples had short duration, as was anticipated. The apples were kept from 57 to 78 days in the one case and from 212 to 243 days in the other.

The following tables give apple weights at the beginning of the test, and the shrinkage and decay losses in terms of weights and of percentages. A few specimens were removed from the cool room after several weeks in order to make flavor comparisons; hence the necessity of the tabular headings "first summary" and "second summary."

TABLE 4. PARAFFIN DIPPING—FRUIT KEPT AT BOOM TEMPERATURE (1913-14)

Treatment	Initial weight ounces	Shrinkage		Decay	
		Ounces	Percent	Ounces	Percent
Jonathan—Nov. 4 to Jan. 9—67 days					
Paraffin	31.	0.7	2.4	20.8	67.1
Check	30.6	4.7	15.2	...	...
Baldwin—Nov. 4 to Jan. 9—67 days					
Paraffin	37.9	1.1	2.8	28.7	75.8
Check	34.9	7.1	20.2	4.	11.5
Fameuse—Oct. 23 to Dec. 24—63 days					
Paraffin	28.4	1.6	5.6	21.5	75.7
Check	28.2	7.4	26.1	10.8	38.4
Red Astrachan—Aug. 27 to Sept. 4—9 days					
Paraffin	45.3	0.1	0.2	17.	37.6
Check	43.9	3.6	8.3	13.9	31.6
Roxbury Russet—Dec. 9 to Jan. 5—28 days					
Paraffin	50.	1.	2.	0	0
Check	48.	10.	20.8	20.	41.7

TABLE 5. PARAFFIN DIPPING. FRUIT IN CELLAR STORAGE (1913-14)

Treatment	Initial weight ounces	Shrinkage		Decay	
		Ounces	Percent	Ounces	Percent
<i>First Summary</i>					
Roxbury Russets—Dec. 9 to Mar. 2—84 days					
Paraffin	72	1	1.4	32	44.4
Check	70	12	17.1	35	50.
Canada Baldwin—Nov. 5 to Mar. 2—118 days					
Paraffin	184	8	4.4	106	57.6
Check	174	21	12.1	44	25.3
Baldwin—Nov. 5 to Mar. 2—118 days					
Paraffin	36	0	0	8	22.2
Check	33	3	9.1	0	0
Ben Davis—Dec. 6 to Mar. 2—87 days					
Paraffin	25	1	4.	0	0
Check	23	3	13.	0	0
<i>Second Summary</i>					
Roxbury Russets—Mar. 2 to Apr. 4—34 days					
Paraffin	35	2	5.7	10	28.6
Check	20	3	15.	17	85.
Canada Baldwin—Mar. 2 to July 6—127 days					
Paraffin	64	2	3.1	62	96.9
Check	74	4	5.4	54	73.
Baldwin—Mar. 2 to July 6—127 days					
Paraffin	28	6	21.4	14	50.
Check	30	7	23.3	14	46.7
Ben Davis—Mar. 2 to July 6—127 days					
Paraffin	21	..	...	5	23.8
Check	17	1	5.9	2	11.8

The general effect of the paraffin coating was greatly to reduce shrinkage, but also to induce early internal decay. The paraffined apples retained their flavor and crispness up to the time of decay. It appears that paraffin forms a coating which is altogether too impervious. The protective work is too well done. It protects as against outside foes but not as against—indeed it favors—disintegration from within. The early internal decay is undoubtedly due to the inhibition of the natural respiratory processes of the fruit, which is smothered much as would be a breathing animal by the closure of its pores, mouth and nostrils by a paraffin dip.

2. MECHANICAL MEDIA

(a) CORK SAWDUST

Cork sawdust is used extensively in packing grapes for shipment. If it keeps grapes from decay it ought to keep apples. It was tested during two seasons. The first year's results were quite satisfactory, save with Rhode Island Greening.

TABLE 6. CORK SAWDUST (1909-10)—KEPT THREE MONTHS

	Shrinkage percentages		Decay percentages	
	Treated	Untreated	Treated	Untreated
Baldwin	3.7	9.4	1.8	5.0
Northern Spy	6.2	9.4	5.0	17.5
Rhode Island Greening....	9.4	10.6	11.9	3.1

As compared with the untreated lots, the Baldwins shrank and decayed somewhat less and the Spys shrank somewhat less and decayed much less when sawdust packed; but the Greenings shrank as much and decayed far more when thus packed. With only one demerit against cork sawdust, namely, the Greening decay loss, it seemed worth while to repeat the trials, which was done with results as follows:

TABLE 7. CORK SAWDUST (1911-12)—KEPT FOUR MONTHS

	Original weight in ounces	First month			Second month			Third month			Fourth month		
		First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces
Baldwin	115.	113.	1	109.	107.5	2	98.	96.8	1	93.	86.5	0	86.5
Northern Spy ...	126.	124.	0	124.	122.5	0	122.5	121.	0	121.	91.8	3	78.5
Rhode Island Greening ...	114	103.5	0	103.5	101.8	0	101.8	100.	0	100.	97.5	2	90.3

	Shrinkage				Decay			
	Treated oz.	Untreated %	Treated oz.	Untreated %	Treated oz.	Untreated %	Treated oz.	Untreated %
Baldwin	11.3	9.8	10.8	8.3	17.3	15.	39.8	30.7
Northern Spy	34.3	27.2	8.8	6.7	13.3	10.5	23.5	18.0
Rhode Island Greening...	16.5	14.5	11.8	10.3	7.3	6.4	26.8	23.4

These figures attest the fact that cork sawdust delays decay but does not retard shrinkage. The decay losses for Baldwin, Northern Spy and Rhode Island Greening were 15.7 percent, 7.5 percent and 17 percent less respectively than occurred with the checks, but the shrinkages were greater by 1.5, 20.5 and 4.2 percents. In other words, the packed Baldwins lost but half as much by decay, the Spys somewhat more than half as much and the Greenings but about a quarter part as much as their checks; but they all shrank more, the Spys four times as much as the checks. Since the essential need is to lessen decay loss, it is evident that cork sawdust serves this purpose well. The increased shrinkages were probably due to the porous nature of the medium.

The results of 3 years' trial of packing fruit in cork sawdust are quite conclusive. It is evidently an excellent medium for apple storage. The flavor of the fruit was unharmed and its general appearance good. The value of cork sawdust in relation to other media is shown on the chart on page 129.

(b) SAWDUST

It is a common practice among farmers to pack apples in sawdust and thus store the fruit for late winter use. The lack of definite information concerning its value and effect on fruit made it advisable to

test its worth for this purpose. Consequently both soft and hard wood sawdust, both wet and dry, were used.

Apples were packed in dry pine sawdust and left therein undisturbed for 3 months with results as follows, expressed in terms of shrinkage in weight and decay loss.

TABLE 8. DRY PINE SAWDUST (1909-10)—KEPT THREE MONTHS

	Shrinkage percentages		Decay percentages	
	Treated	Untreated	Treated	Untreated
Baldwin	11.2	9.4	0	5.
Northern Spy	10.3	9.4	9.7	17.5
Rhode Island Greening	10.	10.6	0	3.1

The shrinkage was quite uniform for the three varieties; and, aside from the Northern Spy, the packed apples suffered no decay. Shrinkage losses as between check lots exposed in open boxes and the packed lots were not widely variant. Repeated trials gave similar results save that decay losses were greater during a four than during a three-month period. Were it not for the rather heavy and uniform shrinkages, the apples would be said to be well preserved, the decay losses being very low. It was noted, however, that the flavor of the fruit packed in pine sawdust was impaired, a piney taste having been apparently to some extent absorbed. The following table shows the behavior of the apples that were stored for a four-month period in moderately dry pine sawdust.

TABLE 9. APPLES IN PINE SAWDUST (1911-12)—KEPT FOUR MONTHS

	Original weight, ounces	First month			Second month			Third month			Fourth month		
		First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces
Baldwin	116.3	114.	3	99.3	97.5	5	75.5	71.	0	71.	69.3	2	61.
Northern Spy	129.5	127.3	0	127.3	124.8	1	119.8	117.	1	112.3	110.	2	99.5
Rhode Island Greening	116.3	113.	0	113.	111.3	0	111.3	111.	1	105.	103.	0	103.

	Shrinkage				Decay			
	Treated oz.	%	Untreated oz.	%	Treated oz.	%	Untreated oz.	%
Baldwin	10.3	8.8	10.8	8.3	45.	38.7	39.8	30.7
Northern Spy	9.8	7.5	8.8	6.7	20.3	15.6	23.5	18.
Rhode Island Greening...	7.3	6.2	11.8	10.3	6.	5.2	26.8	23.4

No advantage was gained in lessening shrinkage, save that the Greenings shrank 4 percent less than the checks. The packed Baldwins decayed 8 percent more than did the checks, the Spys a little less, the Greenings 18 percent less. Apparently the Greenings were the better for the treatment.

Since pine sawdust impaired the flavor of the apples, hardwood sawdust was resorted to. This proved to be much superior to pine sawdust in that it did not impart an undesirable flavor. Moreover, the edible test for flavor indicated a better retention and preservation of flavor in fruit thus stored than in the checks which were held in open boxes; and the shrinkage and decay losses were less than in the check lots.

Trials were conducted to determine the influence of damp sawdust, and to ascertain if the shrinkage losses, which were considerable when dry sawdust was used, could be materially reduced. The sawdust was dampened until it contained 24 percent of moisture and apples were packed therein for test.

The following results were secured in 1910-11: In four months 9.8 percent of the Baldwins, 83 percent of the Northern Spys, and 29.5 percent of the Rhode Island Greenings decayed; and their flavor was materially injured. Apples were packed the same season in sawdust dampened with bordeaux: and 3.5 percent of the Baldwins, 55.8 percent of the Northern Spys and 22.5 percent of the Greenings decayed. Bordeaux was used to cleanse the sawdust of fungi in case such infection was present in the media, and at the same time to surround the apples with a damp media. The outcome was not satisfactory, the decay loss was not checked, the fruit cracked and the flavor was impaired.

The increase in weight and cracking of apples when stored in moist sawdust was unexpected. It seemed due chiefly to the absorption of moisture. The fruit actually gained in weight. Fifteen specimens each of Ben Davis, Roxbury Russet, Tolman Sweet and Bismarck were packed in damp sawdust. At monthly intervals the fruit was unpacked, carefully brushed off and weighed. The apples were packed January 24. Tolman Sweet and Bismarck had decayed badly by March 21 and were discarded. The others were kept two weeks longer. The increases in weight and percentage gains for each month follow:

TABLE 10. APPLES IN WET SAWDUST (1912-13)—KEPT THREE MONTHS

Variety	Date of weighing	Weight in grams	Number of apples	Grams gained	Percentage gain	Total percentage gain
Ben Davis	Jan. 24	1615	15	...	..	..
	Feb. 25	1620	15	5	.3	..
	Mar. 21	1640	15	20	1.2	..
	Apr. 5	1644	15	4	.2	1.8
Bismarck	Jan. 24	2100	12	...	..	..
	Feb. 25	2205	12	105	5.	..
	Mar. 21	2210	12	5	.2	5.2
Roxbury						
Russet	Jan. 24	1210	15	...	..	..
	Feb. 25	1240	15	30	2.5	..
	Mar. 21	1270	15	30	2.4	..
	Apr. 5	1290	15	20	1.6	6.6
Tolman	Jan. 24	1535	15	...	..	..
	Feb. 25	1635	15	100	6.5	..
	Mar. 21	1640	15	5	.3	6.8

Damp sawdust was again used a third season, but in this case the fruit was packed in double paraffin paper in the hopes of preventing splitting of the specimens and of protecting the flavor. The results of this season's trial were:

TABLE 11. DAMP SAWDUST AND DOUBLE PARAFFIN PAPER (1911-12)—KEPT FOUR MONTHS

	Original weight in ounces	First month			Second month			Third month			Fourth month		
		First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces
Baldwin ...	136.5	138.3	4	120.8	120.3	2	111.3	111.5	1	108.	107.5	10	59.5
Northern Spy	173.3	173.5	0	173.5	174.3	4	150.8	150.8	1	145.3	145.3	8	105.3
Rhode Island Greening .	144.	144.5	0	144.5	145.5	0	145.5	145.5	9	106.	104.	13	45.8

SHRINKAGE FOR FOUR MONTHS

	Gain or loss		Decay loss	
	Weight	Percent	Weight	Percent
Baldwin	+1. ounce	+0.7	78. ounces	57.
Northern Spy	+1. ounce	+0.6	69. ounces	39.8
Rhode Island Greening	—0.5 ounce	—0.3	97.8 ounces	67.8

The object of this trial was attained. The fruit did not absorb enough moisture to cause it to split open, although the Baldwins and Spys gained slightly in weight, whereas the Rhode Island Greenings lost. Decay losses were not heavy during the first three months, but the fruit went down quite rapidly during the fourth month. The flavor of the stored fruit was not quite as poor as in previous trials with unwrapped fruit, but nevertheless it was seriously affected.

During the last two seasons apples were wrapped in Oregon paper wrappers and packed in dry sawdust, in order to ascertain the effect on shrinkage and decay. During a three-month period in the second season the decay loss of Baldwin was nil, of Northern Spy 47.2 percent, and of Rhode Island Greening 15.6 percent. During the third season of four months the shrinkage and decay losses were as follows:

TABLE 12. WRAPPERS AND DRY SAWDUST (1911-12)—KEPT THREE MONTHS

	Shrinkage Treated	percentages Untreated	Decay Treated	percentages Untreated
Baldwin	10.	8.3	55.	30.7
Northern Spy	5.5	6.7	29.3	18.
Rhode Island Greening ...	9.6	10.3	3.5	23.4

Shrinkages were identical. The Baldwins and Spys were the worse for protection in that they decayed the faster, the Greenings were the better for it as decay was practically nil.

Comparing the results of wrapper and dry sawdust treatment with the checks, it is seen that the outcome hardly warrants this extra care, although the flavor of the fruit seems protected to a certain extent.

The foregoing trials of sawdust packing seem to warrant the conclusion that fruit packed in exceptionally dry sawdust undergoes considerable shrinkage, but less than in open boxes, due perhaps to the more uniform conditions of temperature and humidity and to the absence of currents of dry air. Fruit packed in damp sawdust absorb moisture and crack, but decay is temporarily checked, probably because of the somewhat lowered temperature. The use of double paraffin paper in connection with damp sawdust hinders the absorption of moisture, thereby preventing splitting, yet flavor is impaired if pine sawdust is used. The sawdust from resinous woods imparts an undesirable taste to the fruit whereas hardwood sawdust does not injure the flavor. If sawdust is to be used at all, it should be of hardwood origin, neither wet nor dry, but slightly moist, clean, pure and fresh.

(c) LEAVES

Dry leaves were used during two different seasons. The first season's results were:

TABLE 13. DRY LEAVES (1909-10)—KEPT THREE MONTHS

	Shrinkage Treated	percentages Untreated	Decay Treated	percentages Untreated
Baldwin	6.7	11.2	14.4	5.
Northern Spy	9.6	11.2	28.9	23.7
Rhode Island Greening ...	10.8	13.1	35.9	3.1

The packed lots shrank less but rotted more than the checks, an unsatisfactory result. When packed in damp leaves, very poor results were attained. The specimens split, the flavor was seriously affected and decay losses were high. The results were so utterly unsatisfactory that no data need be recorded.

Dry leaves were again tried the next season with results as follows:

TABLE 14. DRY LEAVES (1910-11)—KEPT FOUR MONTHS

	Original weight in ounces	First month			Second month			Third month			Fourth month		
		First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces
Baldwin	121.	117.5	0	117.5	102.	0	102.	100.	1	95.5	93.3	3	80.8
Northern Spy.	123.	120.5	1	115.8	113.8	2	104.	102.8	3	89.5	88.	5	63.5
Rhode Island Greening ..	109.	106.5	0	106.5	103.8	1	99.8	97.8	1	91.8	89.5	2	81.5

SUMMARY OF FOUR MONTHS' TEST

	Shrinkage				Decay			
	Treated oz.	%	Untreated oz.	%	Treated oz.	%	Untreated oz.	%
Baldwin	23.3	19.2	10.8	8.3	17.	14.	39.8	30.7
Northern Spy	7.3	5.9	8.8	6.7	52.3	42.5	23.5	18.
Rhode Island Greening...	9.5	8.7	11.8	10.3	18.	16.5	26.8	23.4

The Baldwins shrank 11 percent more, and the Spys and Greenings from 1 to 2 percent less than the checks. The Baldwins and Rhode Island Greenings lost much less by decay than the checks, but the Northern Spys far more. On the whole the results were inconclusive.

(d) SAND

Sand is of finer texture and much more compact than sawdust. It was used on a small scale. Wet sand was tried first, but proved so injurious that its use was early discontinued. Apples in this medium increased in size and in weight and cracked in a short time. The decay losses were large, 39 percent for Baldwin, 71 percent for Northern Spy and 86.8 percent for Rhode Island Greening. Dry sand gave much better results. The first year's test resulted in shrinkage losses, Baldwin 7.5 percent, Northern Spy 5.6 percent, Rhode Island Greening 5.6 percent; and in decay losses, Baldwin 6.9 percent, Northern Spy 23.1 percent, Rhode Island Greening 5.6 percent. Northern Spy kept poorly in all media and so it did in warehouses that year. Dry sand was found to be of no value in checking decay, but it reduced the shrinkage from 2 to 5 percent as compared with the check lots. The flavor of the fruit thus stored was not injured. Still another test was made with dry sand as a medium, the apples being previously wrapped in Oregon paper, to keep the sand from coming into direct contact with the fruit. The results were as follows:

TABLE 15. APPLES IN DRY SAND (1910-11)—KEPT FOUR MONTHS

	Original weight in ounces	First month			Second month			Third month			Fourth month		
		First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces
Baldwin	111.5	110.	1	106.	103.5	1	97.8	96.3	5	75.5	73.8	1	70.3
Northern Spy.	126.5	124.8	1	117.8	116.	2	105.8	99.5	0	99.5	98.	4	78.
Rhode Island Greening ..	116.3	114.5	0	114.5	113.	0	113.	111.3	1	105.5	103.8	0	103.8

SHRINKAGE FOR FOUR MONTHS

	Shrinkage				Decay			
	Treated oz.	%	Untreated oz.	%	Treated oz.	%	Untreated oz.	%
Baldwin	7.3	6.5	10.8	8.3	34.	30.5	39.8	30.7
Northern Spy	11.3	8.9	8.8	6.7	37.3	29.4	23.5	18.
Rhode Island Greening...	6.8	5.8	11.8	10.3	5.8	4.9	26.8	23.4

The shrinkage loss of Northern Spy for four months exceeded that of the checks by 2.2 percent and the decay loss by 11.4 percent. The Baldwins shrank 1.8 percent less and the decay loss was identical.

The Rhode Island Greenings shrank 4.5 percent less and lost 18.5 percent by decay. Clearly dry sand is not a panacea.

(e) CHOPPED HAY

Chopped hay was used as a medium for apple storage during three consecutive years, with fairly consistent results. The flavor of the apples packed in this medium for four-month periods was not injured. Shrinkage and decay losses, however, were high and exceeded those of the checks with but two exceptions in 1911-12.

TABLE 16. CHOPPED HAY (1911-12)—KEPT THREE MONTHS

	Shrinkage percentages		Decay percentages	
	Treated	Untreated	Treated	Untreated
Baldwin	9.5	8.3	23.7	30.7
Northern Spy	8.5	6.7	32.2	18.
Rhode Island Greening.....	7.2	10.3	43.5	23.4

The results attained in the other trials are of a piece with this outcome and need not be further cited. Chopped hay is clearly a poor medium for apple storage. It is not compact and allows of much ventilation. It may also be unsanitary in that it undoubtedly carries bacteria and fungi and thus may become a source of contamination. There is nothing to recommend it.

(f) PAPER WRAPPERS

Paper wrappers were used, not with a view of testing their abstract value but, rather, for comparison with other methods of treatment. The outcome of the third year's trials, which were the most reliable, was very satisfactory for the first three months, but during the fourth month the decay loss was as great as that occurring throughout the first three months, as appears below.

TABLE 17. PAPER WRAPPERS (1910-11)—KEPT FOUR MONTHS

	Original weight in ounces	First month			Second month			Third month			Fourth month		
		First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces	First weight, ounces	Number decayed	Second weight, ounces
Baldwin	120.3	117.5	0	117.5	113.8	1	110.8	109.8	1	105.3	99.5	3	88.3
Northern Spy	138.5	133.	0	133.	133.	0	133.	131.8	1	114.	113.5	5	89.
Rhode Island Greening..	120.5	117.5	1	112.5	110.5	1	105.3	103.5	2	94.	92.	3	78.8

	Shrinkage				Decay			
	Treated oz.	%	Untreated oz.	%	Treated oz.	%	Untreated oz.	%
Baldwin	13.3	11.	10.8	8.3	18.8	15.6	39.8	30.7
Northern Spy	7.8	5.2	8.8	6.7	42.3	30.5	23.5	18.0
Rhode Island Greening...	8.8	7.3	11.8	10.3	33.	27.4	26.8	23.4

The treated Baldwins shrank more than the checks, but decayed less and, contrariwise, the Greenings and Spys shrank less and decayed more than their checks. The differences, however, were not large.

TABLE 18. SUMMARY OF DATA ON SHRINKAGE AND DECAY FOR FOUR MONTHS (1911-1912)

	Baldwin				Northern Spy				R. I. Greenings			
	Shrinkage oz.	%	Decay oz.	%	Shrinkage oz.	%	Decay oz.	%	Shrinkage oz.	%	Decay oz.	%
Checks	10.8	8.3	39.8	30.7	8.8	6.7	23.5	18.	11.8	10.3	26.8	23.4
Dry sawdust, pine	10.3	8.8	45.	38.7	9.8	7.5	20.3	15.6	7.3	6.2	6.	5.2
Cork sawdust.	11.3	9.8	17.3	15.	34.3	27.2	13.3	10.5	16.5	14.5	7.3	6.4
Chopped hay..	11.5	9.5	28.5	23.7	10.	8.5	38.0	32.2	8.3	7.2	49.8	43.5
Dry leaves....	23.3	19.2	17.	14.	7.3	5.9	52.3	42.5	9.5	8.7	18.	16.5
Oregon paper.	13.3	11.	18.8	15.6	7.3	5.2	42.3	30.5	8.8	7.3	33.	27.4
Dry sand	7.3	6.5	34.	30.5	11.3	8.9	37.3	29.4	6.8	5.8	5.8	4.9
Dry sawdust..	11.3	10.	62.	55.	7.3	5.5	38.5	29.3	11.	9.6	4.	3.5
Damp sawdust	1.	.73	78.	57.	1.	.57	69.	39.8	.5	.34	97.8	67.8
	(gain)	(gain)			(gain)	(gain)						
Dipped in bordeaux ...	21.3	21.0	12.5	12.	9.5	14.6	5.5	8.4	5.	5.8	0	0

The following table affords a ready comparison of the results of the different treatments given to three commercial varieties—Baldwin, Northern Spy and Rhode Island Greening during the storage period of 1911-1912. The specimens packed in dry sand and dry sawdust were wrapped in Oregon paper, those in damp sawdust in double paraffin paper, and those dipped in bordeaux in single paraffin paper. The figures attest the following facts: With Baldwin the shrinkage was the least in damp sawdust, and greatest, 21 percent, with the bordeaux treatment; the decay loss with this variety was lowest, 12 percent, with bordeaux, and highest, 57 percent, when packed in damp sawdust. With Northern Spy the shrinkage was the least, 5 percent, with Oregon wrapper paper, and greatest, 15 percent, with bordeaux. The decay loss was lowest, 8 percent, with bordeaux, and highest when packed in dry leaves. With Rhode Island Greenings the shrinkage was the least, .3 percent, in damp sawdust, and greatest, 15 percent, in cork sawdust; the decay loss was nothing with bordeaux, and the highest, 68 percent, in damp sawdust.

(g) BORDEAUX DIPS AND SAWDUST PACK

The satisfactory results obtained with bordeaux and sawdust when employed separately, the one preserving flavor and the other retarding decay, suggested a combination of the two treatments. Four lines of treatment were instituted in the winter season of 1913-14, viz.: Bordeaux dipping, bordeaux dipping and sawdust packing, sawdust packing and untreated controls. Barrel lots of Baldwin, Northern Spys and Rhode Island Greenings were secured, all from the same orchard, thus insuring similar cultural conditions and relative uniformity of fruit. Furthermore, the entire quantity of each variety was carefully graded in preparation for the trials. Following the various treatments the apples were placed in the same basement cellar previously used in these trials, where a fairly uniform temperature prevailed. Ventilation was secured through a window opening at the surface of the ground. Whenever weather conditions permitted, the window was kept open in order to provide a safe and low temperature in the storage room. The apples were stored on November 10 and 11. They were sorted and weighed at very infrequent intervals in order to compare the effect of the different treatments. It was decided to make at least three sortings and more if necessary, in order to remove decayed apples as soon as they became a menace.

The value of any media or any treatment for apples in storage is determined by its influence in hindering shrinkage, retarding decay, preserving the flavor and retaining the general good appearance of the fruit. Shrinkage and decay losses can be accurately measured, but the effect on flavor and appearance can only be judged. For the purposes of this trial an apple was deemed to be decayed when one-half or more was rotten. An arbitrary limit of 15 percent was adopted as the discard point. Whenever the entire number of good apples, including those too good to be discarded, was approximately 15 percent of the original total, the whole lot was discarded. Data secured in this study appears on the succeeding pages, together with a discussion thereof. Attention is called also to the insert plates illustrative of the condition and general appearance of the stored fruit, as well as to the chart (page 129) which graphically set forth the relative worth of the several treatments.

Some Northern Spies kept until July 6. In order to cover the period from November 10 to July 6 with the required comparison of the several treatments, it seems necessary to designate five periods, as shown in the following tables. The shrinkage and decay losses are

given by periods, and are totalized for each period, so that one may follow the rapidity of the changes which took place.

TABLE 19. NORTHERN SPYS. SHRINKAGE AND DECAY LOSSES IN SUCCESSIVE PERIODS AND IN COMBINATIONS OF PERIODS—EIGHT MONTHS, NOV. '13-JULY '14

Treatment	Initial weight, lbs.	Shrinkage, lbs.	Shrinkage, %	Decayed apples, lbs.	Decayed apples, %
First period—Nov. 10 to Jan. 19—71 days					
Check	94.2	4.3	4.5	16.3	17.3
Bordeaux	96.9	0.3	0.3	7.8	8.
Bordeaux and sawdust...	63.4	1.9	3.0	3.6	5.7
Sawdust	86.2	1.8	2.1	3.3	3.8
First and second periods—Nov. 10 to Mar. 27—138 days					
Check	94.2	6.8	7.2	31.9	33.8
Bordeaux	96.9	5.1	5.2	19.8	20.4
Bordeaux and sawdust...	63.4	4.6	7.3	13.3	21.
Sawdust	86.2	3.	3.5	12.6	14.7
Second period—Jan. 19 to Mar. 27—67 days					
Check	73.8	2.5	3.4	15.6	21.2
Bordeaux	88.9	4.8	5.4	12.	13.5
Bordeaux and sawdust...	57.9	2.8	4.8	9.7	16.7
Sawdust	81.1	1.2	1.5	9.3	11.5
First, second and third periods—Nov. 10 to June 1—204 days					
Check	94.2	14.2	15.1	68.8	73.
Bordeaux	96.9	9.6	9.9	62.6	64.6
Bordeaux and sawdust...	63.4	6.3	10.	35.8	56.4
Sawdust	86.2	3.8	4.3	44.7	51.9
Third period—Mar. 27 to June 1—66 days					
Check	55.6	7.4	13.4	36.9	66.4
Bordeaux	72.1	4.5	6.2	42.9	59.5
Bordeaux and sawdust...	45.4	1.7	3.7	22.4	49.4
Sawdust	70.6	0.7	1.	32.1	45.4
First, second, third and fourth periods—Nov. 10 to June 18—221 days					
Check	...	...	...	...	...
Bordeaux	96.9	10.1	10.4	83.3	86.
Bordeaux and sawdust...	63.4	6.9	10.8	49.1	77.5
Sawdust	86.2	4.8	5.6	72.	83.5
Fourth period—June 1 to 18—17 days					
Check	...	...	...	...	...
Bordeaux	24.7	0.5	2.	20.7	83.8
Bordeaux and sawdust...	21.3	0.6	2.6	13.4	62.8
Sawdust	37.8	1.1	3.	27.3	72.2
First, second, third, fourth and fifth periods—Nov. 10 to July 6—239 days					
Check	...	...	...	...	...
Bordeaux	...	...	...	...	...
Bordeaux and sawdust...	63.4	7.1	11.2	54.6	86.2
Sawdust	86.2	4.9	5.7	79.9	92.7
Fifth period—June 18 to July 6—18 days					
Check	...	...	...	...	...
Bordeaux	...	...	...	...	...
Bordeaux and sawdust...	7.3	0.3	3.4	5.5	74.6
Sawdust	9.3	0.1	1.3	7.9	84.

The untreated lot kept less well than its competitors. On June 1st, when this check lot was discarded, its shrinkage and decay losses were high. During the 204 days from November 10 to June 1, the total shrinkages were: check 15 percent, bordeaux 10 percent, bordeaux and sawdust 10 percent, sawdust 4 percent. The decay losses during the same period were: check 73 percent, bordeaux 65 percent, bordeaux and sawdust 56 percent, sawdust 52 percent. Clearly either treatment proved better than no treatment.

The bordeaux-dipped fruit ranked second in keeping qualities. These apples were all discarded on June 18th which was the limit of their preservation under this treatment. The total shrinkage during these 221 days was 10 percent and the decay 86 percent, which were less than the check losses but more than the losses in connection with the other two treatments.

The bordeaux-sawdust and sawdust lots were not discarded in their entirety until July 6. The fruit in each lot stood up about equally well. The bordeaux-sawdust lot had dwindled to 7.3 pounds on July 6, the shrinkage being 3 percent and pound decay loss 75 percent; and sawdust treated fruit weighed 9 pounds, the shrinkage being but one percent while the decay loss was of 84 percent, roughly 10 percent in excess of bordeaux-sawdust losses. The total decay loss when bordeaux and sawdust were used from November 10 to July 6, was 86 percent, in contrast to 93 percent when sawdust alone was used.

The flavor of the apples was given careful consideration, three tests being made prior to June and yet another on July 6 at the close of the trial. The bordeauxed apples tasted best and the sawdust packed lot suffered most. The flesh of the bordeauxed apples possessed that desirable flavor which is characteristic of fruit that is well ripened or well preserved. It was of normal color, sweet and crisp. The apples that were packed in sawdust seemed to lack life, seemed somewhat shrivelled, to have lost in palatability, indeed to possess a woody taste, though not enough so to be repellent. The check apples tasted better than those packed in sawdust, and the bordeaux-sawdust lot did not taste quite as good as did the bordeaux treated specimens.

In brief it may be said that bordeaux dipping best preserved the Northern Spy flavor, while the combined bordeaux dip and sawdust pack best protected the fruit against decay.

The Rhode Island Greenings were dipped, packed or left untreated as the case might be, and placed in storage on November 11, approximately 100 pounds being used in each lot. They were kept

until July 17, ten days longer than the Spys. The several sortings occurred on February 3, March 28, May 11, June 18, July 6 and 17. The relative rates of shrinkage and decay under the different treatments are shown in some detail in the following progressive tables:

TABLE 20. RHODE ISLAND GREENINGS. SHRINKAGE AND DECAY LOSSES IN SUCCESSIVE PERIODS, AND IN COMBINATION OF PERIODS—EIGHT MONTHS, NOV. '13-JULY '14

Treatment	Initial weight, lbs.	Shrinkage, lbs.	Shrinkage, %	Decayed apples, lbs.	Decayed apples, %
First period—Nov. 11 to Feb. 3—84 days					
Check	105.1	3.8	3.6	12.1	11.5
Bordeaux	103.6	4.9	4.7	14.1	13.6
Bordeaux and sawdust ...	96.9	3.8	3.9	12.5	12.9
Sawdust	103.6	3.6	3.5	16.6	16.1
First and second periods—Nov. 11 to Mar. 28—137 days					
Check	105.1	5.9	5.6	31.1	29.6
Bordeaux	103.6	4.9	4.8	22.1	21.4
Bordeaux and sawdust ...	96.9	6.	6.2	16.5	17.
Sawdust	103.6	4.3	4.2	38.8	37.4
Second period—Feb. 3 to Mar. 28—53 days					
Check	89.2	2.1	2.3	18.9	21.2
Bordeaux	84.6	0.1	0	8.	9.5
Bordeaux and sawdust ...	80.6	2.2	2.7	4.	5.
Sawdust	83.3	0.8	0.9	22.1	26.6
First, second and third periods—Nov. 11 to May 11—181 days					
Check	105.1	7.6	7.3	88.6	84.2
Bordeaux	103.6	5.8	5.5	40.1	38.7
Bordeaux and sawdust ...	96.9	6.7	6.9	26.9	27.7
Sawdust	103.6	5.1	5.	70.6	68.1
Third period—Mar. 28 to May 11—44 days					
Check	68.2	1.8	2.6	57.5	84.3
Bordeaux	76.6	0.8	1.1	18.	23.5
Bordeaux and sawdust ...	74.4	0.7	0.9	10.4	14.
Sawdust	60.4	0.8	1.2	31.8	52.6
First, second, third and fourth periods—Nov. 11 to June 18—219 days					
Check	105.1	...	...	...	...
Bordeaux	103.6	8.4	8.1	83.4	80.5
Bordeaux and sawdust ...	96.9	8.6	8.8	57.9	59.7
Sawdust	103.6	9.	8.7	89.9	86.8
Fourth period—May 11 to June 18—38 days					
Check	...	...	...	...	...
Bordeaux	57.8	2.7	4.7	43.3	75.
Bordeaux and sawdust ...	63.3	1.9	3.	31.	49.
Sawdust	27.9	3.9	13.9	19.3	69.3

TABLE 20.—CONTINUED

Treatment	Initial weight, lbs.	Shrinkage, lbs.	Shrinkage, %	Decayed apples, lbs.	Decayed apples, %
First, second, third, fourth and fifth periods—Nov. 11 to July 6—237 days					
Check	...	...	...	...	...
Bordeaux	103.6	9.2	8.9	92.8	89.5
Bordeaux and sawdust...	96.9	9.	9.3	68.2	70.4
Sawdust	...	...	...	...	...
Fifth period—June 18 to July 6—18 days					
Check	...	...	...	...	...
Bordeaux	11.8	0.8	6.4	9.3	79.3
Bordeaux and sawdust...	30.4	0.4	1.4	10.3	33.9
Sawdust	...	...	...	...	...
First, second, third, fourth, fifth and sixth periods—Nov. 11 to July 17—249 days					
Check	...	...	...	...	...
Bordeaux	...	...	...	...	...
Bordeaux and sawdust...	96.9	9.7	10.	76.3	78.8
Sawdust	...	...	...	...	...
Sixth period—July 6 to July 17—12 days					
Check	...	...	...	...	...
Bordeaux	...	...	...	...	...
Bordeaux and sawdust...	19.7	0.7	3.5	8.1	41.3
Sawdust	...	...	...	...	...

The shrinkages were: checks 7 percent, bordeaux 6 percent, bordeaux and sawdust 7 percent, sawdust 5 percent. The losses from decay were: checks 84 percent, sawdust 68 percent, bordeaux 39 percent, bordeaux-sawdust 28 percent. The untreated apples decayed rapidly, the losses being three times those which occurred when bordeaux-sawdust was used, more than twice those that occurred when bordeaux dipping was employed, and nearly a quarter more than occurred in the sawdust pack.

The checks kept for 181 days, until May 11, before being discarded; those packed in sawdust for 219 days, until June 18, those immersed in bordeaux for 237 days, until July 6, and those immersed in bordeaux and packed in sawdust for 248 days, until July 17. These periods of durability are considerable in themselves and mean much in terms of apple storage. To keep a lot of apples for more than two months longer than another lot similar in character but dissimilarly treated, is a matter of some importance. The commercial value of any product two months out of season is greatly enhanced. The Rhode Island Greenings that were dipped in bordeaux and packed in sawdust kept in part for more than 8 months until July 17, the shrinkage and decay losses being 10 and 79 percents respectively. The flavor was best

preserved by bordeaux dipping, although the apples receiving the bordeaux-sawdust treatment were scarcely inferior thereto. Those packed in sawdust partook very slightly of the flavor or taste of the media, but were not distasteful. The bordeauxed apples best retained their appearance. Considerable scald developed on the untreated apples by midwinter, but this malady did not affect the treated fruit.

The Baldwins were graded and dipped or packed on November 11, approximately 100 pounds being used in each lot. Some of them were kept until August 5, a month later than any of the Spys. The several sortings occurred on February 21, March 28, May 22, July 6, 17 and 28 and August 5. The apples in the control lot were sufficiently decayed by May 22 to warrant discarding them. The data appear herewith.

TABLE 21. BALDWINs. SHRINKAGE AND DECAY LOSSES IN SUCCESSIVE PERIODS AND IN COMBINATIONS OF PERIODS—NINE MONTHS, NOV. '13-AUG. '14

Treatment	Initial weight, lbs.	Shrinkage, lbs.	Shrinkage, %	Decayed apples, lbs.	Decayed apples, %
First period—Nov. 11 to Feb. 21—102 days					
Check	113.6	10.7	9.4	9.8	8.6
Bordeaux	105.8	4.4	4.1	5.2	4.9
Bordeaux and sawdust....	111.5	5.4	4.8	4.	3.6
Sawdust	100.6	2.6	2.6	12.4	12.3
First and second periods—Nov. 11 to Mar. 28—137 days					
Check	113.6	10.8	9.5	23.2	20.4
Bordeaux	105.8	5.1	4.9	9.1	8.6
Bordeaux and sawdust....	111.5	6.2	5.6	8.4	7.6
Sawdust	100.6	3.4	3.4	22.6	22.4
Second period—Feb. 21 to Mar. 28—35 days					
Check	93.1	0.1	0.1	13.4	14.4
Bordeaux	96.2	0.8	0.8	3.9	4.1
Bordeaux and sawdust....	102.1	0.8	0.8	4.4	4.4
Sawdust	85.6	0.8	0.9	10.2	11.9
First, second and third periods—Nov. 11 to May 22—192 days					
Check	113.6	14.3	12.6	88.3	77.8
Bordeaux	105.8	6.8	6.4	29.2	27.6
Bordeaux and sawdust...	111.5	6.8	6.1	18.3	16.4
Sawdust	100.6	4.1	4.1	57.8	57.5
Third period—Mar. 28 to May 22—55 days					
Check	79.6	3.5	4.4	65.1	81.9
Bordeaux	91.5	1.6	1.8	20.1	21.9
Bordeaux and sawdust....	96.9	0.6	0.6	9.8	10.1
Sawdust	74.6	0.8	1.	35.3	47.2
First, second, third and fourth periods—Nov. 11 to July 6—237 days					
Check	...	...	...	...	...
Bordeaux	105.8	11.6	11.	73.4	69.4
Bordeaux and sawdust...	111.5	10.7	9.6	54.6	48.9
Sawdust	100.6	8.2	8.1	84.8	84.3

TABLE 21.—CONTINUED

Treatment	Initial weight, lbs.	Shrinkage, lbs.	Shrinkage, %	Decayed apples, lbs.	Decayed apples, %
Fourth period—May 22 to July 6—45 days					
Check	...	...	...	...	...
Bordeaux	69.8	4.9	7.	44.2	63.3
Bordeaux and sawdust ...	86.5	3.9	4.6	36.3	42.
Sawdust	38.6	4.1	10.5	26.9	69.7
First, second, third, fourth and fifth periods—Nov. 11 to July 17—248 days					
Check	...	...	...	...	...
Bordeaux	105.8	11.9	11.3	91.4	86.4
Bordeaux and sawdust....	111.5	11.6	10.4	62.8	56.3
Sawdust	100.6	8.7	8.6	86.8	86.3
Fifth period—July 6 to July 17—11 days					
Check	...	...	...	...	...
Bordeaux	20.8	0.3	1.5	18.	86.8
Bordeaux and sawdust....	46.3	0.8	1.9	8.2	17.7
Sawdust	7.6	0.5	6.6	2.	26.2
First, second, third, fourth, fifth and sixth periods—Nov. 11 to July 28—259 days					
Check	...	...	...	...	...
Bordeaux	...	...	...	...	...
Bordeaux and sawdust....	111.5	11.8	10.6	76.3	68.4
Sawdust	...	...	...	...	...
Sixth period—July 17 to July 28—11 days					
Check	...	...	...	...	...
Bordeaux	...	...	...	...	...
Bordeaux and sawdust....	37.2	0.3	0.7	13.5	36.3
Sawdust	...	...	...	...	...
First, second, third, fourth, fifth, sixth and seventh periods—Nov. 11 to Aug. 5—267 days					
Check	...	...	...	...	...
Bordeaux	...	...	...	...	...
Bordeaux and sawdust....	111.5	11.9	10.7	91.4	82.
Sawdust	...	...	...	...	...
Seventh period—July 28 to Aug. 5—8 days					
Check	...	...	...	...	...
Bordeaux	...	...	...	...	...
Bordeaux and sawdust....	23.4	0.1	0.3	15.2	64.8
Sawdust	...	...	...	...	...

The untreated lot shrank one-eighth in weight in 6 months, which was thrice what the sawdust pack lost. More than three-fourths of the control lot of apples decayed in 6 months, while but one-sixth of those dipped in bordeaux and packed in sawdust were thus lost. This latter treatment was notably successful. It was not until August 5, nearly 9 months from the time they were treated and stored, that the decay was as far advanced as was that of the control lot at 6 months or the other two lots at 8 months. Or, to rephrase and make more

specific this comparison, it may be said that 15 percent of the apples stored November 11 were still in good condition on the following dates:

ControlOn May 22, 192 days after storing.

BordeauxOn July 17, 248 days after storing.

Bordeaux-sawdust ...On August 5, 267 days after storing.

SawdustOn July 17, 248 days after storing.

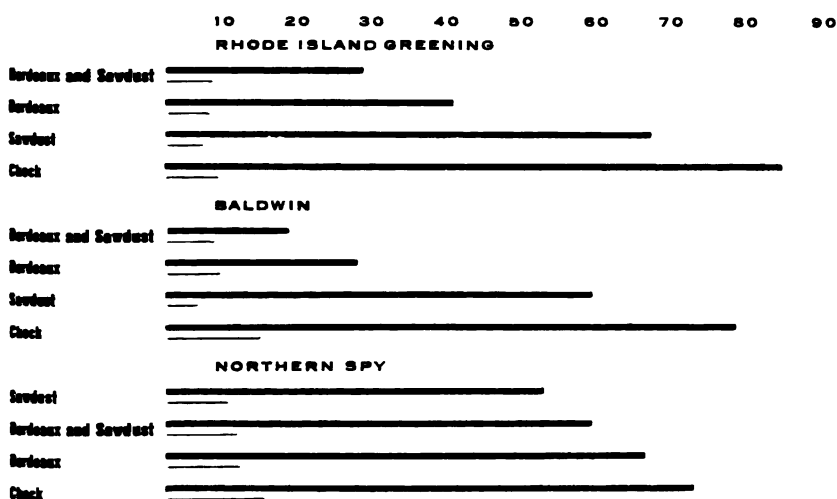
The outcome of the flavor tests was the same as with the Northern Spy and Rhode Island Greenings. It was best preserved by bordeaux, with bordeaux-sawdust a good second. The check apples lost in flavor, while those packed in sawdust developed a very slight woody flavor.

The general appearance of the apples dipped in bordeaux was most attractive. As long as they remained in good condition they were fresh and plump, and, aside from a slight trace of bordeaux coloration in the stem and calyx ends, there were no signs of the bordeaux immersion.

In view of the favorable results obtained with the bordeaux-sawdust treatment, one may inquire as to the use a farmer or orchardist may make of this discovery. It is not the present purpose to discuss the full range of application of this new principle of apple storage; but a single suggestion may be of interest. In the first place the bordeaux-sawdust treatment is not applicable to commercial quantities of apples. It is only of service to the man who is concerned in the preservation of the family supply and who lacks good storage facilities. Many varieties keep till midwinter in moderately good storage quarters. It is the late winter, spring or even early summer supply that calls for special treatment. It will therefore be necessary only to give special attention to the fruit designed for late use. To this end the author suggests, first of all, the careful grading of the fruit and the use only of perfect specimens. The apples may then be immersed in a 5-5-50 bordeaux mixture for ten minutes. The use of a gunny sack expedites the immersion. They should then be allowed to dry and, before packing, should be cooled to as low a temperature as practicable, so be it they do not freeze. As the packing in hardwood sawdust proceeds, a plentiful supply of the filling material should be used in order to keep the individual specimens somewhat asunder. The sawdust should be well firmed. The barrel should be stored in a cool and cleanly place. Once a supply of good hardwood sawdust has been provided, it may be used repeatedly.

There is no cause for anxiety in connection with the use of bordeaux. The apples will be but slightly and locally colored with the

antiseptic solution. Chemical analyses were made late in the storage period with a view of ascertaining the amount of copper salts on the apples and scarcely a trace could be detected. However, if the apples are pared no possible danger can befall. It should be remembered that a much longer interim elapses between immersion and use in the case of storage, than elapses between orchard spraying with bordeaux and the utilization of fall apples which go into market at an early date. No one who was not looking for bordeaux would be likely to observe the faint spots in the cavities of apples.



Graph illustrative of relative losses following various methods of treatment. Shrinkage —————, decay ————.

TEMPERATURE OF APPLE STORAGE ROOM

The records in the subjoined tables show the temperature conditions surrounding the fruit during the trial periods. The temperature of the storage room was higher each month in 1910-11 than that of any of the media and its range was greater. In 1911-12 the highest temperatures were consistently recorded in the dry and cork sawdusts.

The winter of 1913-14 was unusually cold and hence exceptionally favorable to the long preservation of apples. The storage room was kept at as low a temperature as was compatible with safety without an unreasonable amount of attention. The thermometer readings given below indicate how successful were these efforts. The temperature of the fruit, all of which was in barrels, was a little lower than the room temperature.

In all cases the temperature was too high for the best preservation of the fruit. Furthermore too great a range of temperature prevailed

for successful storage. However, the conditions were such as commonly occur in many farm cellars and indicate the problem that farmers have to face in the storage of apples.

TABLE 22. AVERAGE MONTHLY TEMPERATURES (°F.) OF MEDIA AND OF STORAGE ROOM

Media	Dec.	Jan.	Feb.	Mar.	Range	Average for entire year		
1910-1911								
Dry sawdust	38.	37.1	37.6	34.7	3.3	36.85		
Chopped hay	39.5	38.4	38.4	38.7	1.1	38.75		
Dry leaves	39.4	38.7	38.5	36.6	2.8	38.3		
Wet leaves	38.6	39.6	38.	35.5	4.1	37.93		
Paper wrappers	39.7	39.2	38.4	38.9	1.3	39.05		
Wet sand	36.1	37.3	37.1	37.4	1.3	36.98		
Storage room	41.1	44.6	41.7	40.1	4.2	41.8		
1911-1912								
Dry sawdust	41.9	35.7	33.9	37.7	8.	37.3		
Cork sawdust	41.9	36.5	34.6	38.2	7.3	37.8		
Chopped hay	41.7	35.3	32.4	36.9	9.3	36.58		
Dry leaves	40.9	34.8	32.1	35.6	8.8	35.85		
Dry sand	39.7	34.1	31.6	36.3	8.1	35.42		
Damp sawdust	38.5	33.	29.4	32.7	9.1	33.40		
Storage room	41.9	35.3	33.5	37.4	8.4	37.03		
1913-1914								
Sawdust	40.2	38.6	36.	38.8	37.9	51.3	60.1	24.1
Control	40.5	38.4	36.	38.7	38.7	50.7	59.3	23.3
Storage room.	42.2	41.2	37.3	41.2	41.	56.2	62.8	25.5

The 1913-14 data are based on from 19 to 26 readings each month. An average statement for the entire period seems futile because June is quite unlike February.

III. STRUCTURAL CHARACTERS IN RELATION TO STORAGE

It is a well known fact among orchardists that certain varieties of apples keep better than do others. The possibility that structural characters might have something to do with the keeping qualities of certain varieties led the writer to make preliminary studies with the Roxbury Russet, Ben Davis and Baldwin apples, with especial reference to the structural characteristics of the skin and flesh. Of the common varieties in Vermont, probably the Roxbury Russet will keep the longest, while Ben Davis scarcely takes second place. The Baldwin, Northern Spy and Rhode Island Greening, which are midwinter

sorts, are about equally durable in storage. The first named varieties were chosen for study because of their extreme keeping qualities, and the latter named because of their commercial importance and because they were used in the trials thus far discussed in this bulletin.

Fruit of uniform size and ripeness were selected so as to insure comparable conditions for histological observations. Sections were cut from the flesh about an eighth of an inch below the skin, and from these pieces cellular material was scraped off and mounted in water. From each mounted portion a number of free cells were drawn with the aid of a camera lucida. The surface area of these cells were then determined by the use of a planimeter and expressed in terms of square millimeters. The average areas of three varieties were found to be: Roxbury Russet, .03059 sq. mm. (465 cells); Ben Davis, .03734 sq. mm. (323 cells); Baldwin, .04084 sq. mm. (368 cells).

The cells of the Roxbury Russet, which keeps the longest, are smaller than those of the Ben Davis, and of necessity the intercellular spaces are proportionately small. The Baldwin cells and intercellular

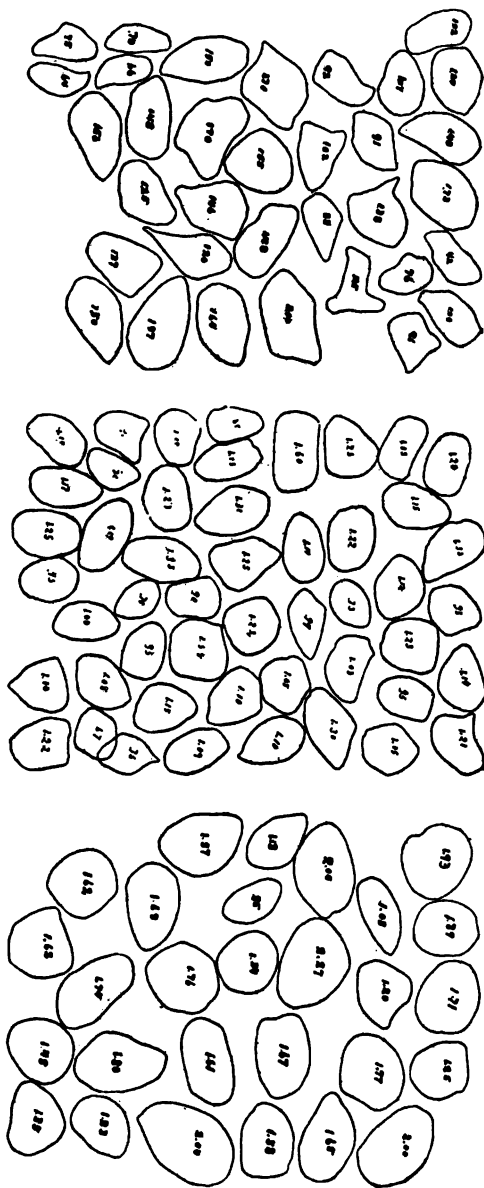


FIG. 1. Relative sizes of cells in flesh of Ben Davis at top, Roxbury Russet in middle, and Baldwin at bottom.

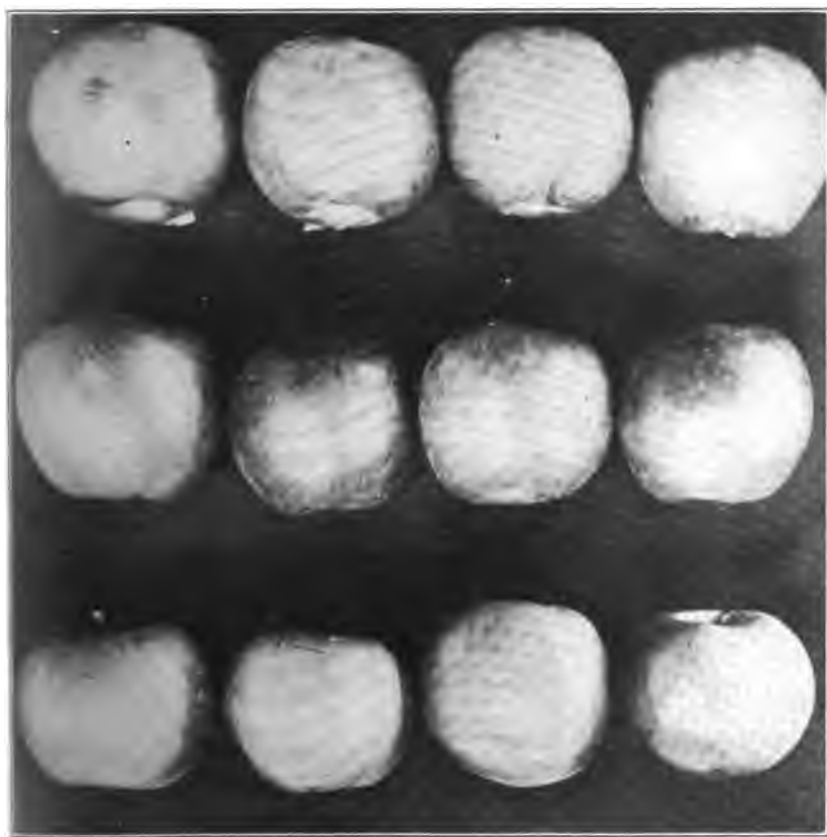
spaces are larger than those of Ben Davis. The larger the cells and spaces the greater the porosity of the flesh. Compactness of cell structure and the consequent smallness of the intercellular spaces in apples is believed to retard the interchanging of gases and may be a factor influencing the good keeping qualities of some varieties. At least there seems to be some correlation between the closeness of cell structure and the keeping capabilities of different varieties. The accompanying plate shows representative sheets of drawings of the cells of the three varieties used in these studies.

The skin structure in relation to keeping qualities was next studied. The four varieties selected were: Roxbury Russet, Ben Davis, Rhode Island Greening and Oldenburg, representing four groups.

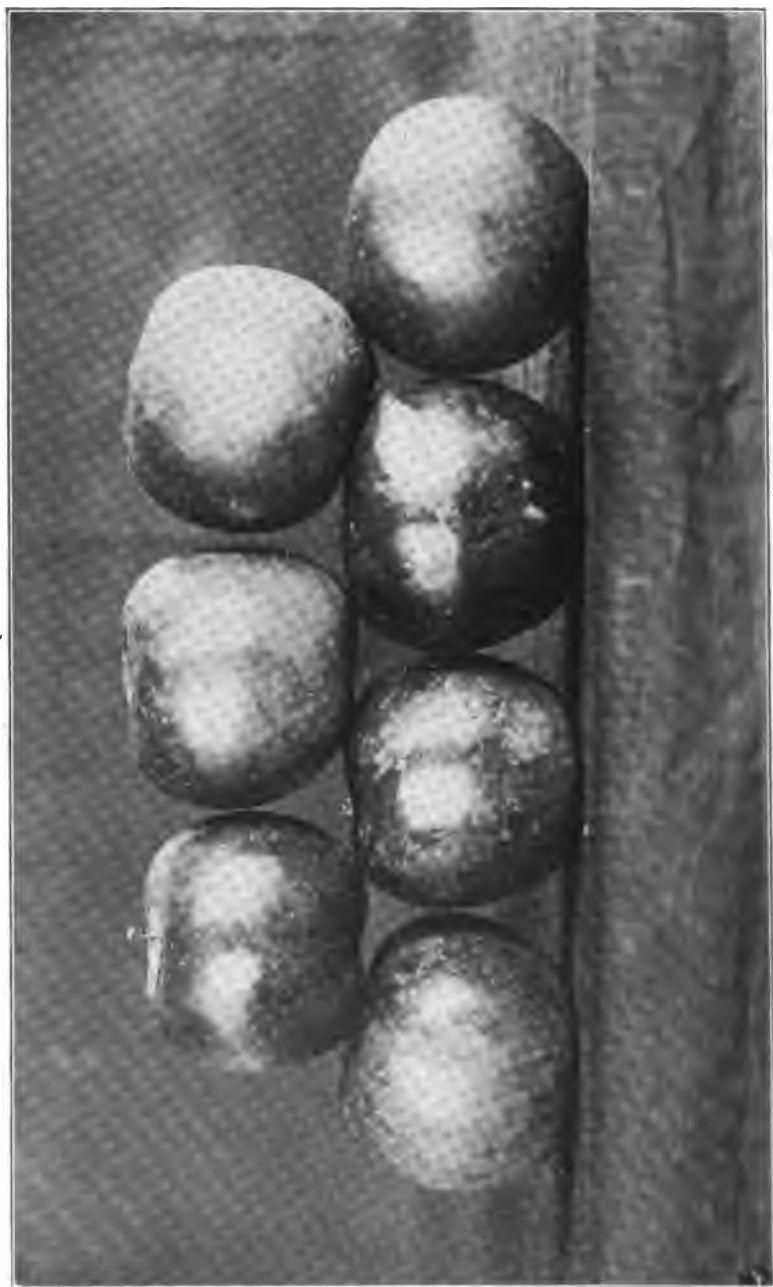
Hedrick¹ states that there are 12 varieties in the Russet group, described as ranging from small to medium or above in size, russet colored, with peculiarly fine-grained, dense texture, of sprightly flavor, and of good keeping qualities; that there are 13 in the Ben Davis group, rather large, bright red, coarse and solid in texture, of indifferent flavor, and with thick skin, good shippers and keepers; that the Rhode Island Greening is commercially the most valuable and best representative of the Reinette group which contains 56 varieties, it being rather large in size, of green or yellow ground color, with or without blush, and of good quality; and that the Oldenburg group consists of 24 varieties ranging from medium to large in size, variously striped with red, generally ripening in the fall and of short season.

Plugs of apple tissue were cut from two specimens of each variety, fixed in "Flemming's third," and, after being thoroughly washed, completely dehydrated by means of alcohol. From 100 percent alcohol they were passed into xylol, thence on to paraffin, melting at 45° C. The paraffin when cold was cut into rectangular blocks 2 and 3 c. c. long, each containing a portion of apple flesh. These were trimmed, and sectioned 6 mm. thick. Several sections were stained with gentian violet and mounted in Canada balsam with satisfactory results. The cuticle took the stain less deeply than the cell walls, and the distinction was not enough, especially with Roxbury Russet, to enable one to make good camera lucida drawings. The contents of the first four layers of cells adjoining the cuticle, which contains much oil, resin, etc., were stained even darker than the cell walls.

¹N. Y. (State) Sta. Bul. 275 (1906).



**Rhode Island Greenings, Baldwins, Northern Spys immersed in Bordeaux,
and packed in sawdust. Photo taken June 19, 1914.**



Baldwins immersed in Bordeaux and packed in sawdust. Photo taken July 28, 1914.

In order to bring out more clearly the cutinized layer, other sections were stained with safranin, which is prepared by mixing equal volumes of aniline water and a concentrated alcoholic solution of safranin. This was allowed to act for a half hour or more on the sections, after which they were bleached in acid-alcohol. This stain brought out the cuticle clearly, but it was with difficulty that the cuticular walls were distinguished. Böhmer's haematoxylin was used to stain these walls. It was allowed to act from 50 to 75 seconds on sections stained with safranin and washed, which were then mounted in Canada balsam. The cellular walls were stained blue, the cutinized layer red and the cell contents a very dark red. This procedure gave very satisfactory sections for study under the compound microscope after the fruit has attained the size of walnuts, excepting in cases of too rapid gaseous interchange.

Suberization, involving the development and deposition of cork, is a process of occasional occurrence on the skin of fruits. Cork tissue appears around wounds and may also be seen around lenticels. As a rule, the walls of corky tissue are thin and in some instances suberized throughout. The suberization or waterproofing of the wall is accomplished by chemical changes in the original cellulose wall and by additions of suberin layers to this wall, or by the latter process alone. Suberin is quite similar to cutin in its chemical composition and it takes a very deep red stain with safranin.

A number of lenticels were observed in apple skin, but no stomates were found. According to Zschoke,¹ "stomata cease to functionate and several camera lucida drawings were made of each variety at a magnification of 360."

The epidermis is the first—and often the only—protective tissue formed, and because of its location, must bear the brunt of adverse conditions. Its chief value lies in the protection which it gives against a too rapid loss of water and, probably, too rapid an exchange of gases in the process of respiration. All terrestrial plants of any size would lose water faster than they can absorb it but for the protection which the epidermis affords. The efficiency of the epidermis in preventing this loss is seen by comparing the loss where the epidermis is removed with that where it is intact. For instance, two apples, one pared and the other unpared, were hung up in a dry atmosphere; the former lost a third of its weight in 2 days and the latter 1 percent.

¹"Ueber den Bau der Haut und die Ursachen der verschiedenen Haltbarkeit unserer Kernobstfrüchte." *Landwirtschaft Jahrb d'Schweiz*. XI. Bd.; pp. 153-196 (1897).

The epidermis undergoes modification to meet its needs and fulfill its purposes. Cutinization of the outer wall is one of the common modifications. The process consists in the deposition of a waxy substance intermixed with nearly pure cutin, together with some unaltered cellulose which is infiltrated with oils and waxes. This change in the chemical and mechanical structure of the cuticular layer and the epidermis in general seems to be quite common in the late keeping varieties, like Roxbury Russet and Ben Davis. Such changes in skin structure aid materially in furnishing protection against abrasion and against smooth thin-skinned varieties which are mostly summer, fall and early winter kinds." The formation of stomata seems to be possible on fruit as long as the epidermal cells remain soft and thin walled. From 120 to 180 stomata per square millimeter then exist. In the more mature fruit we find only from 6 to 9 stomata per square millimeter, since the same number is now divided over a surface about 20 times larger.

The cuticular layers, or the first several layers of cells beneath the cuticle, vary in size, shape and in their degrees of suberization in the four varieties studied. The Roxbury Russet has a cuticle which is remarkably thick as compared with that of the other varieties studied, as is shown in Fig. 2. The survey of a large number of slides with the aid of a stage and ocular micrometer enables the statements that the cuticle was .0417 millimeter in thickness. Not only was the membrane of the epidermal cells thickened and cutinized throughout its entire extent, but the same was the case with some cells to the third and fourth layer of tissue. The Roxbury Russet cells are smaller, more compact and more suberized than those of most varie-

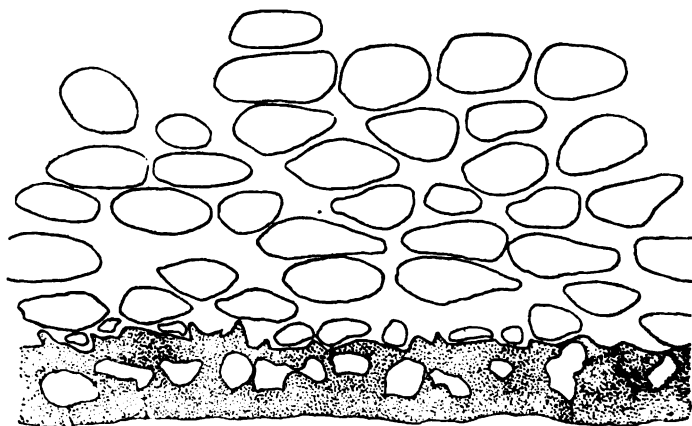


FIG. 2. Roxbury Russet showing thick cuticle, suberized cells, and compact tissue composed of small thick walled cells.

ties. The cells of the cuticular layer increase in size and decrease in their degree of suberization in the order previously noted. The cells next to the suberized layer are ovate in shape, gradually becoming rounded in the deeper flesh.

The Ben Davis apple resembles the Roxbury Russet in many of its general characteristics and keeps in storage quite as well. In minute structures this variety was found to possess a cuticular layer resembling that of Roxbury Russet, the cells being thickened to the third and fourth layer, the tissue there being very compact. The cuticle was found to be 0.239 millimeter in thickness. Fig. 3.

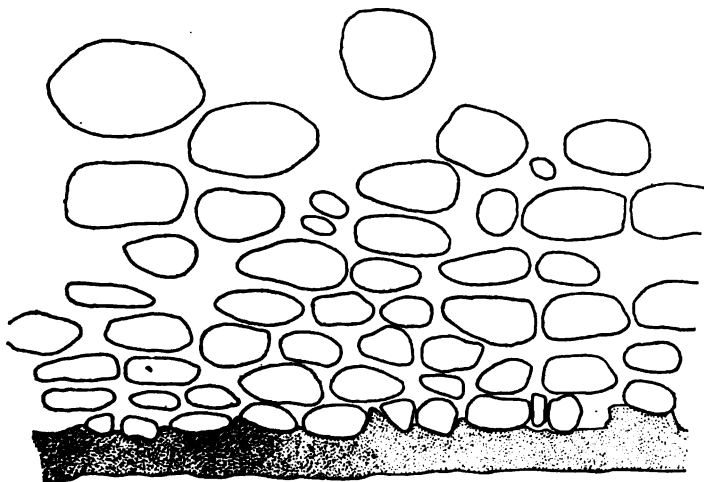


FIG. 3. Ben Davis showing thickened walls of epidermal and subepidermal cells to depth of several layers.

The Rhode Island Greening possesses a less conspicuous cuticular layer. It contains fewer cells, they are thinner in wall structure and consequently furnish less protection to the flesh within. This variety has a shorter life period in storage. The cuticular layer measured .0217 millimeter in thickness. See Fig. 4.

The Oldenburg, Fig. 5, is an early fall apple having a thin cuticle which measured .0178 millimeter in thickness. The cuticular layer undergoes very little suberization. There is no gradual increase in size of cells through to the deeper flesh, but a sudden transition from small to large cells with large intercellular spaces.

The space between the cells as shown in the plates does not all represent intercellular area. It is made up mostly of cell walls. The larger and further apart the cells, the larger is the intercellular space.

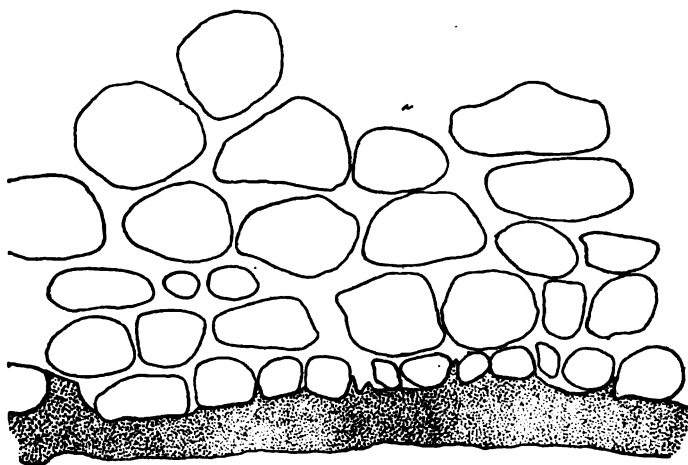


FIG. 4. R. I. Greening showing less thickening of subepidermal cells than occurs in Ben Davis.

The relation of structural characteristics to the keeping qualities of the fruits is a close one, within certain limits. The apples studied represent not merely horticultural groups but definite seasonal varieties and while the number of kinds discussed is small, the results indicate a degree of relationship of no small importance. Structural character seems to play a part in the preservation of apples. Thus the Oldenburg, a fall apple, has a relatively thin skin with thin-walled cells underneath; the Baldwin, a midwinter variety, has a rather porous flesh with large, intercellular spaces, and a moderately thick skin; the Ben Davis and Roxbury Russet, late keeping varieties, have smaller cells, more compact tissues and thicker skins, which seem to undergo modification during development. The deposition of oils, waxes, tannins and suberins in the epidermal regions, chiefly in the cuticular layer, which seems more characteristic of the last named than the earlier named varieties, renders fruit less subject to mechanical injuries, and more impervious to gaseous interchange and moisture losses.

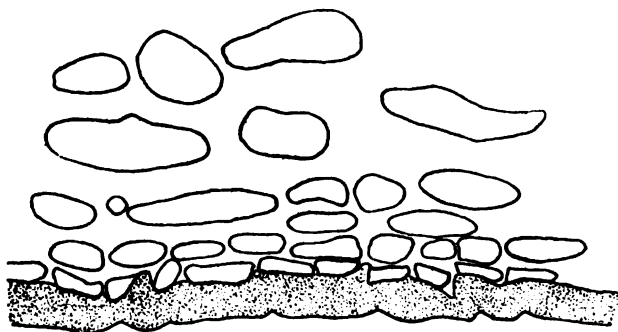


FIG. 5. Oldenburg with relatively thin cuticular layer characteristic of fall apples.

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AND STATE AGRICULTURAL COLLEGE

VERMONT AGRICULTURAL
EXPERIMENT STATION
BURLINGTON, VT.

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Cultivation

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BULLETIN 187: FLORA OF VERMONT

List of Ferns and Seed Plants Growing Without Cultivation

PREPARED BY VERMONT BOTANICAL CLUB

INTRODUCTION

The Vermont Botanical Club issued their first edition of the State Flora in 1900. During the fifteen years that have since elapsed there has been marked botanical activity, not only among the members of the Vermont Club, but among professional students of the northeastern United States. The two standard manuals for this region—the Gray Manual and the Britton and Brown Illustrated Flora—have during this period appeared in carefully revised editions, that present many additional species and numerous changes in nomenclature.

Some four years ago the Vermont Botanical Club appointed a committee to prepare a revised edition of the State Flora, consisting of W. W. Eggleston of the Bureau of Plant Industry, Washington, D. C., George L. Kirk of Rutland, and J. G. Underwood of Hartland. These gentlemen have labored with diligence and enthusiasm, and have had the cooperation of the active members of the Club. The result of their labors is presented in this new edition of the Vermont Flora.

A special effort has been made to report with more thoroughness the distribution of plants in eastern Vermont. When the former edition was prepared there was no working botanist in that part of the State. The editors were dependent for information chiefly upon the herbarium of Mr. C. C. Frost of Brattleboro (who died in 1880) and upon Prof. Henry G. Jesup's Catalogue of Flowering Plants found within thirty miles of Hanover, N. H., covering a tract fully half of which is in Vermont. As an indication of the help that has since come to hand may be mentioned:

1. The herbarium of Dr. F. Blanchard, now in the Fairbanks' Museum.
2. A list of plants found in eastern Vermont by Mr. W. H. Blanchard.
3. A similar list prepared by the Hartland Nature Club.
4. A list prepared by Mrs. Mack and Miss Strong of Woodstock.
5. A list of the West River Valley plants by Lester A. Wheeler of Townshend.
6. The plants of St. Johnsbury and vicinity by Miss Bridget M. Rooney.

Also for northern Vermont invaluable aid has been given by the admirable reports on the Flora of Willoughby by Dr. Geo. G. Kennedy (Rhodora 6: 91-134, June, 1904), and on the Flora of Burlington and

vicinity in 1911 by Mrs. Nellie F. Flynn. Other botanists from without the State have found the Green Mountains attractive hunting ground for rare plants, and have published lists that have been of great assistance in the preparation of the new edition. To these and to all helpers, whether lovers of plant life in Vermont or members of the goodly fraternity of professional botanists, the committee would gratefully acknowledge their indebtedness.

In the present catalogue all names of species, varieties, and formae are printed in boldface type; and for two special reasons this list follows the nomenclature of the revised Gray Manual. First, the great majority of the members of the Vermont Botanical Club use this manual, as more convenient to handle and less expensive than the Illustrated Flora; and secondly, the committee believe, that, whatever might be their personal opinion when these two authorities differ regarding the proper name for a species, it would be confusing and obtrusive to follow now the one authority and now the other. They therefore decided to continue the practice adopted in the former edition, and when the two authorities give different names, to print after the Gray Manual name the Britton and Brown name in parenthesis, and to include all such synonyms in the index. Unfortunately these synonyms, as may be seen by comparing the two editions of the Vermont Flora, are far more numerous in the second edition than in the first; so that the proposed efforts at uniformity have not as yet met with marked success.

The synonymy has also been largely increased along a different line—by the free introduction of English names, in accordance with the growing practice of all our manuals. The greatly diminished study of Greek and Latin even in our universities, and the keen popular interest in the study of Natural History have made the old technical names of species to many meaningless and embarrassing; and the demand for "English names," in spite of their frequent ambiguity—it would seem—must needs be met. From these two causes the synonyms in the index have been more than doubled.

But the technical names printed in darker type have also been increased from two causes:—First, more careful and extended explorations have disclosed forms of plant life in Vermont not before recognized; and secondly, our expert authorities, especially in New England, have become more keen-sighted and more disposed to distinguish, as species or varieties, forms that before had passed under one name. In these two ways alone the total number of names of

species, varieties, forms and hybrids (barring all synonyms) has been increased from 1,563 in the former edition to 2,006 in the present edition. For the Pteridophyta (the Ferns and their Allies), and for the three largest families and seven of the more critical genera of Seed-plants we obtain the following instructive record:—

	NUMBER OF NAMES IN THE LIST OF 1915, OF 1900					PER CENT. OF INCREASE	
	SPECIES*	VAR.	SUB. VAR.	HYBRIDS	TOTAL	TOTAL	
All Families	1,694	130	133	65	2,022	1,562	29 1/8
Pterodophyta . . .	73	10	29	16	128	81	58
Cyperaceæ	162	37	17	3	219	192	14
Compositæ	181	13	29	1	224	171	31
Graminæ	151	7	7	0	165	130	27
Carex	111	35	8	3	157	135	16
Cratægus	28	5	11	0	44	7	528 1/2
Viola	23	2	0	16	41	16	156
Rubus	17	1	0	15	33	16	106
Panicum	27†	1	0	0	28	19	47
Scirpus	22	1	6	0	29	20	45
Juncus	19	6	0	0	25	15	67

*When a species is represented in the State by a variety only, it is counted as a species and not as a variety.

†Including three species transferred to *Digitaria* and *Echinochloa*.

In the edition of 1900 three "Supplementary Lists" were given of plants reported in earlier Vermont catalogues, but omitted because no corroborative specimens could be found. It was anticipated that many of these species would be rediscovered; and so it has proved. In such cases the names have been inserted in the present edition; and as these lists have largely served their purpose, they are not re-published. But an interesting paper might be written on the tasks undertaken to release certain of these species from the purgatory into which they were thrust by the compilers of the list published in 1900.

One other supplementary list in our last edition calls for a brief comment—a list, largely conjectural, of plants that have been introduced into Vermont from other parts of the United States. There is no practical difficulty in distinguishing, for a region as large as that covered by the Gray Manual, plants that are indigenous from those that have come in through man's agency from Eurasia or tropical America—those whose names are printed in the Gray Manual with small capitals. But it is a different problem to separate, for a region as small as Vermont, plants indigenous to the State from those that have been introduced from without. In some instances there can

be no reasonable doubt that the species has been recently naturalized from another State. The common Locust (*Robinia Pseudo-Acacia*), the greenhouse and garden pest *Oxalis repens*, the three species of *Phlox*—*P. paniculata*, *P. stolonifera*, and *P. subulata*—are examples; and a score or more might be cited. But one familiar with the localities in which such species occur, as *Myosotis arvensis*, *Chenopodium capitatum*, *Mimulus moschatus*, may not say with confidence that they have in all instances been introduced into Vermont. The solution of such a problem must be deferred, at least till our knowledge of the distribution of the species and of its constant environment is well nigh complete.

The publication of the revised Flora is made under the auspices of the Vermont Experiment Station, and under the direction of Dr. George P. Burns, Secretary of the Vermont Botanical Club, and Professor of Botany in the University of Vermont. Much of the editorial work has been in charge of Mrs. Nellie F. Flynn of Burlington, and Dr. Brainerd has assisted in the proof-reading and in the preparation of the index.

For a clear understanding of the text the following explanations should be kept in mind.

1. All preferred names of species and varieties are printed in boldface type, including foreign plants, or those not indigenous to the territory covered by the Britton and Brown Illustrated Flora or the Gray Manual. These foreign plants, however, are designated in the Vermont Flora by an asterisk placed after the specific or varietal name.

2. After the name in boldface type is given in parenthesis any synonym preferred by Dr. Britton in the Illustrated Flora, and in some instances a synonym that was used in the previous edition of the Vermont Flora.

3. In indicating the degree of frequency of occurrence, four adjectives have been used with a careful attempt at precision, namely, "common," "frequent," "occasional," "rare." In each case this statement regarding frequency is to be associated with the accompanying statement regarding habita—thus "sandy soil, common" means common on sandy soils; and such a plant may be rare in other habitats. Where they are abundant in such stations the word "local" has been preferred. In cases where but five stations or less were known, there have been enumerated, the name of the collector following in parenthesis.

4. The usage of the Gray Manual has been observed in giving a separate paragraph or line to a marked variety; while a subordinate variety or a form has been noted in the same paragraph with the type.

5. When a hybrid has received a special name, that name has been first given in the list, preceded by the sign x and followed in parenthesis by the usual formula indicating the accredited parentage of the hybrid. Only 65 spontaneous hybrids have been listed for Vermont.

EZRA BRAINERD,
President of the Vermont Botanical Club.

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FLORA OF VERMONT

PTERIDOPHYTA. FERN PLANTS

POLYPODIACEAE. FERN FAMILY

ADIANTUM. Maidenhair

- A. pedatum* L. Rich moist woods; common.

ASPIDIUM. (DRYOPTERIS). Shield Fern

- X *A. Bootii* Tuckerm. (*A. cristatum* x *spinulosum*, var. *intermedium*).
Boot's Shield Fern. Wet thickets and about ponds; occasional.
- A. cristatum* (L.) Sw. Crested Shield Fern. Moist thickets and swamps; frequent.
- A. cristatum* (L.) Sw., var. *Clintonianum* D. C. Eaton. (*D. Clintoniana* [D. C. Eaton] Dowell). Clinton's Shield Fern. Swampy woods; frequent.
- A. Filix-mas* (L.) Sw. Male Fern. Hartland, (Nancy Darling); Woodstock and Bridgewater, (Mabel A. Strong); Barnard, (Miss F. E. Corne); Brandon, (Kirk and Dutton). *forma incisum* Clute. Brandon, (Kirk and Dutton).
- A. fragrans* (L.) Sw. Fragrant Fern. Mt. Mansfield, Camel's Hump, and Bolton Notch, (Pringle); Mt. Zion, Hubbardton, (Ross and Eggleston).
- A. Goldianum* Hook. Goldie's Fern. Rich moist woods; occasional.
- A. marginale* (L.) Sw. Marginal Shield Fern. Rocky woods; common.
Var. *elegans* J. Robinson. Swampy woods; occasional.
- A. noveboracense* (L.) Sw. New York Fern. Moist woods and swamps; common.
- X *A. pittsfordense* (Slosson) Eastman. (*A. marginale* x *spinulosum*).
Pittsford, (Margaret Slosson); Hartland, (Nancy Darling).
- A. simulatum* Davenp. Massachusetts Fern. Rare. Brattleboro, (Mrs. F. B. Horton); Hartland, (Mrs. Hurd).
- A. spinulosum* (O. F. Müller) Sw. Spinulose Shield Fern. Damp woods; occasional.
- A. spinulosum* (O. F. Müller) Sw., var. *dilatatum* (Hoffm.) Gray, *forma asadenium* Robinson. (*D. dilatata* [Hoffm.] Gray). Broad Shield Fern. Mountain woods; common above 2,500 feet altitude.
- A. spinulosum* (O. F. Müller) Sw., var. *intermedium* (Muhl.) D. C. Eaton. (*D. intermedia* [Muhl.] Gray). Woodlands; common.
- A. Thelypteris* (L.) Sw. Marsh Fern. Swamps and wet places; common.

Additional Hybrid Forms

- A. cristatum* x *cristatum*, var. *Clintonianum*. In tracts where plants of the species and its variety are numerous intermediate forms are usually frequent.

- A. cristatum x marginale.** Pittsford, (Margaret Slosson).
A. cristatum x spinulosum. Middlebury, (Brainerd).
A. cristatum, var. Clintonianum x Goldianum. Middlebury, (Brainerd 1879).
A. cristatum, var. Clintonianum x marginale. Pittsford, (Margaret Slosson); Middlebury, (Brainerd).
A. cristatum, var. Clintonianum x spinulosum. Middlebury, (Brainerd); Pittsford, (Margaret Slosson).
A. cristatum, var. Clintonianum x spinulosum, var. intermedium. Middlebury, (Brainerd); Montgomery, (Mary L. Gates).
A. Filix-mas x marginale. North Bridgewater, (Winslow); Barnard, (Miss F. E. Corne); Brandon, (Underwood).
A. Goldianum x marginale. Leicester, (Brainerd); Cavendish, (Rugg).
A. Goldianum x spinulosum, var. intermedium. Middlebury, (Brainerd 1879).
A. marginale x spinulosum, var. intermedium. Orleans, (Winslow).
A. spinulosum x spinulosum, var. intermedium. Where numerous plants of species and variety grow together, intergrading forms are not infrequent.

ASPLENIUM. Spleenwort

- A. acrostichoides** Sw. (*A. thelypteroides* Michx.; *Athyrium thelypteroides* [Michx.] Desv.). Silvery Spleenwort. Rich woods; frequent.
- A. angustifolium** Michx. (*A. pycnocarpon* Spreng). Narrow-leaved Spleenwort. Rich moist woods; occasional. North in the Connecticut Valley to St. Johnsbury.
- X **A. ebenoides** R. R. Scott. (*Asplenium platyneuron x Campsorus rhizophyllus*). Scott's Spleenwort. On limestone; rare. Rutland, (G. H. Ross); Pittsford, (Grace A. Woolson); Brandon, (Dutton); Salisbury, (Dr. H. H. Swift); Proctor, (Kirk).
- A. Filix-femina** (L.) Bernh. (*Athyrium Filix-foemina* [L.] Roth). Lady Fern. Moist woods; common. A variable species with many described forms.
- A. platyneuron** (L.) Oakes. (*A. ebenum* Alt.). Ebony Spleenwort. Rocky woods; frequent. North in the Connecticut Valley to St. Johnsbury. Var. *incisum* (E. C. Howe) Robinson. (*A. ebenum*, var. *Hortoniae* Davenp.). With type; rare. Brattleboro, (Mrs. F. B. Horton); Pittsford, (Katherine A. French). Var. *serratatum* (E. S. Miller) BSP. With type; rare. Pittsford, (Grace A. Woolson).
- A. Ruta-muraria** L. Rue Spleenwort. Limestone cliffs of western Vermont; occasional. Lake Willoughby, (E. Faxon).
- A. Trichomanes** L. Maidenhair Spleenwort. Shaded cliffs; frequent. Var. *incisum* Moore. Brattleboro, (Frost, Annie L. Grout); Norwich, (Jesup); Pittsford, (Rugg).

A. viride Hudson. Green Spleenwort. Cliffs, Mt. Mansfield and Camel's Hump, (Pringle); Mt. Hor, Westmore, (Mrs. Condit); Plymouth Notch, (Mabel A. Strong).

A. Trichomanes x *Ruta-muraria*. Proctor, (Grace A. Woolson).

CAMPTOSORUS. Walking Leaf

C. rhizophyllus (L.) Link. Walking Fern. Shaded rocks, especially limestone; locally common in western Vermont. Plymouth Notch, Hartland, Brattleboro, Williamstown, Norwich and Windsor in the Connecticut Valley.

CRYPTOGRAMMA. Rock Brake

C. Stelleri (Gmel.) Prantl. (*Pellaea gracilis* Hook.). Slender Rock Brake. Moist limestone rocks; occasional. Hartland, Quechee Gulf, East Barnet and St. Johnsbury in eastern Vermont.

CYSTOPTERIS. (FILIX). Bladder Fern

C. bulbifera (L.) Bernh. Common Bladder Fern. Moist shaded ravines and cliffs; frequent.

C. fragilis (L.) Bernh. Fragile Bladder Fern. Rocky woods and ravines; common.

DICKSONIA. (DENNSTAEDTIA)

D. punctilobula (Michx.) Gray. (*D. pilosiuscula* Willd.). Hay-scented Fern. Hilly pastures; common. *Forma cristata* (Maxon) Clute. With the type; occasional.

ONOCLEA

O. sensibilis L. Sensitive Fern. Moist places; common. Var. *obtusilobata* (Schkuhr) Torr. With type; occasional.

O. Struthiopteris (L.) Hoffmann. (*Matteuccia Struthiopteris* [L.] Todaro). Ostrich Fern. Rich alluvial soil; common. A form similar to the var. *obtusilobata* of *O. sensibilis* has been found in Dorset, (Mrs. E. H. Terry).

PELLAEAE. Cliff Brake

P. atropurpurea (L.) Link. Purple Cliff Brake. Limestone cliffs; occasional in western Vermont. Mt. Willoughby and Quechee Gulf in eastern Vermont. Var. *Bushii* Mackenzie. Essex Junction, (C. E. Faxon); Burlington, (Blake); West Haven, (Kirk).

PHEGopteris. (DRYopteris). Beech Fern

P. Dryopteris (L.) Fée. Oak Fern. Moist woods and swamps; common.

P. hexagonoptera (Michx.) Fée. Broad Beech Fern. Rich woods; occasional. North in the Connecticut Valley to St. Johnsbury.

P. polypodioides Fée. (*D. Phegopteris* [L.] C. Chr.). Long Beech Fern. Damp woods; common.

POLYPODIUM. Polypody

- P. vulgare** L. Rocks; common. Var. *attenuatum* Milde. Brattleboro, (Addie L. Reed). Var. *auritum* Willd. Mt. Horrid, (Dutton). Var. *cambricum* (L.) Willd. Rutland, (Kirk); Montgomery, (Mary L. Gates).

POLYSTICHUM

- P. acrostichoides** (Michx.) Schott. (*Aspidium acrostichoides* Sw.). Christmas Fern. Rocky woods; common. Var. *incisum* Gray. (*Aspidium acrostichoides*, var. *incisum* Gray; *Polystichum acrostichoides*, var. *Schweinitzii* Small). Rhod. 11: 35. Dry wooded hill-sides; frequent. Crisped and crested forms occur.
- P. Braunii** (Spenner) Fée. (*Aspidium aculeatum*, var. *Braunii* Döll.). Braun's Holly Fern. Moist woods above 1500 feet altitude; occasional.

PTERIS. (PTERIDIUM). Brake or Bracken

- P. aquilina** L. Pastures and open woods; common. Var. *pseudo-caudata* Clute. Burned over place, Colchester, (F. A. Ross).

WOODSIA

- W. alpina** (Bolton) S. F. Gray. (*W. hyperborea* R. Br.). Alpine Woodsia. Mt. Mansfield and Willoughby, (Pringle); Quechee Gulf, (Balch).
- W. glabella** R. Br. Smooth Woodsia. Willoughby Lake, (Torrey); Mt. Mansfield and Bakersfield Ledge, (Pringle); Quechee Gulf, (Balch); Mt. Horrid, Rochester, (Dutton).
- W. ilvensis** (L.) R. Br. Rusty Woodsia. Rocks; common.
- W. obtusa** (Spreng.) Torr. Blunt-lobed Woodsia. Rocky banks and calcareous ledges; occasional. In Connecticut Valley north to St. Johnsbury.

WOODWARDIA. (ANCHISTEA). Chain Fern

- W. virginica** (L.) Sm. Virginia Chain Fern. Fort Ethan Allen pond, (Robbins); Franklin bog, (Wild); Rutland, (Kirk).

OSMUNDACEAE. FLOWERING FERN FAMILY

OSMUNDA. Flowering Fern

- O. cinnamomea** L. Cinnamon Fern. Wet woods and pastures; common. Forma *bipinnatifida* Clute. Fern Bull. 15: 17. Williston, (Blake). Forma *frondosa*, (T. & G.) Britton. With the type; occasional. Forma *incisa* (Huntington) Gilbert. With the type; occasional. Forma *latipinnula* Blake. Rhod. 15:155. Swanton, (Blake). A crisped form occurs.
- O. Claytoniana** L. Interrupted Fern. Wet woods and pastures; common. Var. *dubla* Grout. Newfane, (Grout).
- O. regalis** L. Royal Fern. Wet woods and swamps; common. Forma *interrupta* Milde. Swanton, (Blake). Forma *orbiculata* Clute. Hartland, (Ruggles). An incised form occurs.

OPHIOGLOSSACEAE. ADDER'S TONGUE FAMILY**BOTRYCHIUM. Moonwort**

- B. lanceolatum** (Gmel.) Angstroem, var. **angustisegmentum** Pease & Moore. Lance-leaved Grape Fern. Moist hollows in cool open woods; rare.
- B. Lunaria** (L.) Sw. Moonwort. Very rare. Willoughby House, Westmore, (G. H. Tilton).
- B. obliquum** Muhl. (*B. ternatum* forma *obliquum* Milde). Grape Fern. Moist gravelly slopes; frequent. Var. **dissectum** (Spreng.) Clute. (*B. dissectum* Spreng.). Cool loamy soil, open fields; occasional. Var. **oneldense** (Gilbert) Waters. Vermont, Miss Gilman, Gray's Manual ed. 7.
- B. ramosum** (Roth) Aschers. (*B. matricariaefolium* A. Br.; *B. neglectum* Wood). Rich moist woods; occasional.
- B. simplex** E. Hitchcock. Little Grape Fern. Hilly pastures and open woods; occasional. Var. **compositum** (Lasch) Milde. Hartland, (Nancy Darling); St. Johnsbury, (Bridget M. Rooney).
- B. ternatum** (Thunb.) Sw., var. **intermedium** D. C. Eaton. (*B. silaifolium* Presl.). Ternate Grape Fern. Old pastures and copses; occasional. Var. **rutaeifolium** (A. Br.) D. C. Eaton. (*B. matricariae* Spreng.). Old fields; rare.
- B. virginianum** (L.) Sw. Rattlesnake Fern. Rich woods; common.

OPHIOGLOSSUM. Adder's Tongue

- O. vulgatum** L. Moist meadows and pastures; occasional.

EQUISETACEAE. HORSETAIL FAMILY**EQUISETUM. Horsetail**

- E. arvense** L. Common Horsetail. Moist gravelly or sandy banks; common.
- E. fluviatile** L. (*E. limosum* L.). Pipes. Shallow water with muddy bottom; common. A form with the branches bearing numerous small spikes occurs, Burlington, (Mrs. N. F. Flynn).
- E. hyemale** L., var. **affine** (Engelm.) A. A. Eaton. Common Scouring Rush. Moist gravelly banks; common. Forma **polystachyum** Prager. Burlington, (Blake).
- E. hyemale** L., var. **intermedium** A. A. Eaton. Scouring Rush. Moist sandy soil, Burlington, (Howe).
- E. litorale** Kühlewein. Shore Horsetail. Gravelly shores of Lake Champlain; rare.
- E. palustre** L. Marsh Horsetail. Wet sandy shore of Lake Champlain, Burlington, (Pringle); Brandon, (Dutton); Windsor, (W. H. Blanchard, Rugg); Colchester, (Blake).
- E. pratense** Ehrh. Newark, (Kennedy); Brattleboro, (Wheeler).
- E. scirpoides** Michx. Moist cool woods; occasional.
- E. sylvaticum** L. Moist shady places; common.
- E. variegatum** Schleicher. Gravelly shores; occasional.

- E. variegatum** Schleicher, var. **Jesupi** A. A. Eaton. Wet shores; rare. Forma **geminatum** Blake. Rhod. 15:156. Essex Junction, (Blake). Forma **multirameum** Blake. Rhod. 15:156. Essex Junction, (Blake).

LYCOPODIACEAE. CLUB MOSS FAMILY

LYCOPODIUM. Club Moss

- L. annotinum** L. Cold woods; common. Var. **pungens** Desv. Summit Mt. Mansfield, (Pringle); Brighton, (W. H. Blanchard).
L. clavatum L. Common Club Moss. Dry woods; common. Var. **megastachyon** Fernald & Bissell. (Var. **monostachyon** Gray's Manual, ed. 7). Rhod. 12: 53. Dry woods; occasional above 1,000 feet altitude.
L. complanatum L. Willoughby, (Winslow and Rugg); Hartland, (Florence H. Sturtevant).
L. complanatum L., var. **flabelliforme** Fernald. Ground Pine. Dry pastures and open woods; common. Var. **Wibbel** Haberer. Westmore, (Kennedy); Brandon, (Dutton); Hartland, (Underwood).
L. inundatum L. Bog Club Moss. Moist soil; occasional. Var. **Bigelovii** Tuckerm. Sunderland, (Grout).
L. lucidulum Michx. Shining Club Moss. Cold damp woods; common.
L. lucidulum Michx., var. **porophillum** (Lloyd & Underwood) Clute. Cold ravine, Clarendon, (Kirk).
L. obscurum L. Tree Club Moss. Moist woods; occasional. In the Connecticut Valley north to St. Johnsbury.
L. obscurum L., var. **dendroideum** (Michx.) D. C. Eaton. Tree Club Moss. Moist woods; common.
L. sabinaefolium Willd. Dry woods and pastures; Rochester, (Eggleston); Willoughby, (Winslow and Rugg); Hartland, (Nancy Darling).
L. Selago L. Summits of Mansfield and Camel's Hump, (Robbins); Johnson, (Eggleston); Rochester, (Dutton).
L. Selago L., var. **patens** (Beauv.) Desv. Smugglers' Notch, (Pringle).
L. stichense Rupr. Willoughby Mt., (Winslow and Rugg).
L. tristachyum Pursh. (**L. complanatum** L., var. **Chamaecyparissus** Milde). Dry woods and pastures; occasional.

SELAGINELLACEAE

SELAGINELLA

- S. apus** (L.) Spring. Creeping Selaginella. Moist shady places; Brattleboro, (Grout); Pownal, (Hazen).
S. rupestris (L.) Spring. Rock Selaginella. Dry exposed rocks; frequent. In the Connecticut Valley north to Barnet.

ISOETACEAE. QUILLWORT FAMILY

ISOETES. Quillwort

- I. Dodgei** A. A. Eaton. (**I. canadensis** A. A. Eaton). Firm soil, borders of ponds and streams; occasional.

- I. echinospora* Dur., var. *Braunii* (Dur.) Engelm. (*I. Braunii* Dur.).
Margins of ponds and streams; common.
- I. echinospora* Dur., var. *muricata* (Dur.) Engelm. (*I. Braunii* Dur.).
Mouth of Pompanoosuc River, Norwich, (Jesup).
- I. macrospora* Dur. Willoughby Lake, (Kennedy).
- I. Tuckermanni* A. Br., var. *borealis* A. A. Eaton. Grout Pond, Stratton,
(Eggleston and Grout).

SPERMATOPHYTA. SEED PLANTS

TAXACEAE. YEW FAMILY

TAXUS. Yew

- T. canadensis* Marsh. Ground Hemlock. Moist banks and hills; frequent.

PINACEAE. PINE FAMILY

ABIES. Balsam Fir

- A. balsamea* (L.) Mill. Cold, wet woods and swamps, in the higher altitudes; common. Not reported in the Connecticut Valley south of Hartland.

JUNIPERUS. Juniper

- J. communis* L., var. *depressa* Pursh. (*J. sibirica* Burgsd.). Common Juniper. Dry, sterile hills; frequent. In the Connecticut Valley, north to Peacham.
- J. horizontalis* Moench. (*J. Sabina* L., var. *procumbens* Pursh.). Manchester, (Mary A. Day).
- J. virginiana* L. Red Cedar. Dry, rocky hills; frequent in lower altitudes of western Vermont and north in the Connecticut Valley to Fairlee.

LARIX. Larch

- L. laricina* (Du Roi) Koch. Tamarack. Cold swamps; common, except in the lower Connecticut Valley.

PICEA. Spruce

- P. canadensis* (Mill.) BSP. (*P. alba* Link). White Spruce. Common in northeastern Vermont south to Strafford, West Fairlee and Newbury. Its western limit is a line drawn from Strafford through East Barre, East Montpelier, Craftsbury and Albany to Newport Center, (W. H. Blanchard); Hartland, (Nancy Darling); Newfane, spreading from cultivation, (Wheeler); Providence Island, common, (Jones); Thompson's Point, Colchester, (Griffin); Essex, (Howe).
- P. mariana* (Mill.) BSP. (*P. nigra* Link; *P. brevifolia* Peck). Swamp or Black Spruce. Common in sphagnum swamps of the Champlain

- and upper Connecticut Valleys. *Forma semiprostrata* (Peck) Blake. Summit of Mt. Mansfield, (Eggleston).
- P. rubra** (Du Roi) Dietr. (*P. rubra* Link; *P. rubens* Sarg.). Red Spruce. Common, especially on rocky mountain sides.

PINUS. Pine

- P. Banksiana** Lambert. (*P. divaricata* Sudw.). Gray Pine, Jack Pine. Monkton, (R. E. Robinson); Starksboro, (Pringle); Fairfax, (Bates). But few trees at each station.
- P. resinosa** Ait. Red or Norway Pine. Dry, rocky soil; frequent.
- P. rigida** Mill. Pitch Pine. Barren, sandy soil. Common in the northern Champlain Valley and in the Connecticut River towns north to Wells River.
- P. Strobus** L. White Pine. Common up to 1000 feet altitude.

THUJA. Arbor Vitae

- T. occidentalis** L. Commonly but wrongly called White Cedar. Swamps and rocky banks; common in northern and central Vermont, occurring in eastern Vermont south to Hartland and Woodstock.

TSUGA. Hemlock

- T. canadensis** (L.) Carr. Rocky woods and swamps; common.

TYPHACEAE. CAT-TAIL FAMILY

TYPHA. Cat-tail

- T. angustifolia** L. Narrow-leaved Cat-tail. Marshes; occasional.
- T. latifolia** L. Common Cat-tail. Marshes; common.

SPARGANIACEAE. BUR-REED FAMILY

SPARGANIUM. Bur-reed

- S. americanum** Nutt. (*S. simplex*, var. *Nuttallii* Engelm.). Bogs and muddy shores. Burlington, (Mrs. N. F. Flynn); Fairfield Pond, (Blake).
- S. americanum** Nutt., var. *androcladum* (Engelm.) Fernald & Eames. (*S. simplex* Huds., var. *androcladum* Engelm.; *S. androcladum* [Engelm.] Morong.). Bogs and shallow water; common.
- S. angustifolium** Michx. Shallow water in mountain ponds; frequent.
- S. diversifolium** Graebner. (*S. simplex* Gray's Manual, ed. 6, in part). Marshy borders of ponds and streams; frequent.
- S. diversifolium** Graebner, var. *acaule* Fernald & Eames. (*S. acaule* [Beeby] Rydb.). Essex Junction, Hinesburg Pond, Williston, (Blake).
- S. eurycarpum** Engelm. Borders of ponds and rivers; frequent in western Vermont.
- S. fluctuans** (Morong) Robinson. (*S. androcladum* Morong, var. *fluctuans* Morong in part). Floating in ponds; occasional.

- S. lucidum* Fernald & Eames. Shore of Winooski River, near mouth, Burlington, (Blake).
S. minimum Fries. Marshy borders of ponds; occasional.
S. simplex Huds. Marshy borders of ponds and streams; frequent.

NAJADACEAE. PONDWEED FAMILY

NAJAS. Naiad

- N. flexilis* (Willd.) Rostk. & Schmidt. Slow streams and ponds; common.

POTAMOGETON. Pondweed

- P. alpinus* Balbis. (*P. rufescens* Schrad.). Windsor, (Jesup); Willoughby Lake, (E. Faxon); Lewis Creek, Ferrisburg, (E. & C. E. Faxon); Harvey's Pond, W. Barnet, (Blanchard); Little Averill Pond, (Eggleston).
P. americanus C. & S. (*P. lonchites* Tuckerm.). In sluggish streams; frequent.
P. amplifolius Tuckerm. Common in still water; fruiting more commonly at high altitudes.
P. angustifolius Berchtold & Presl. (*P. Zizii* Mertens & Koch). Alburg, (Morong); Milton, (Grout). Var. *connecticutensis* (Robbins) Benn. (*P. lucens* L., var. Robbins). Lake Dunmore, (E. Faxon); Lake Bomoseen, (Eggleston).
P. bupleuroides Fernald. (*P. perfoliatus* Gray's Manual, ed. 6, in part, not L.). Occasional in Lake Champlain.
P. confervoides Reichenb. (*P. Tuckermani* Robbins). Grout Pond, Stratton, (Grout).
*P. crispus** L. In shallow water, Lake Champlain and tributaries. Malletts Bay, (Griffin); Ferrisburg and Charlotte, (Dutton and Kirk).
P. dimorphus Raf. (*P. Spirillus* Tuckerm.). Common.
P. ephedrus Raf. (*P. Nuttallii* C. & S.; *P. pennsylvanicus* Willd.). Still or flowing water; common.
P. ephedrus Raf., var. *cayugensis* (Wiegand) Bennett. In Winooski River, Burlington, (Blake).
X *P. Faxoni* Morong. Abundant in the still water of Lake Champlain and tributaries.
P. filiformis Pers. (*P. marinus* auth., not L.?). In Lake Champlain, Charlotte, (Dutton and Kirk); West Haven, (Kirk).
P. foliosus Raf. (*P. pauciflorus* Pursh.). Lewis Creek, Ferrisburg, (C. E. Faxon); W. Barnet, (Blanchard); Brattleboro, (Grout); Woodbury, (Brainerd); Burlington and Colchester, (Mrs. N. F. Flynn).
P. foliosus Raf., var. *niagarensis* (Tuckerm.) Morong. Tributaries of Lake Champlain; occasional.
P. Friesii Rupr. (*P. mucronatus* Gray's Manual, ed. 6, not Schrad.?). Frequent.
P. heterophyllus Schreb. Still or flowing water; common. Forma *graminifolius* (Fries) Morong. Knight's Island, Lake Champlain,

- (Brainerd). *Forma terrestris* Schlecht. Exsiccated places; frequent.
- P. hybridus** Michx. (*P. diversifolius* Raf.). "South Hero," (Robbins); "Brattleboro," (Frost); Vernon, (Grout); Willoughby, (Jesup).
- P. lucens** L. Ponds; local.
- P. natans** L. Pools and ditches; common.
- P. Oakesianus** Robbins. Grout Pond, Stratton; Lily Pond, Vernon, (Grout).
- P. obtusifolius** Mertens & Koch. Fairlee Lake, (Jesup and Sargent); Little Otter Creek, Ferrisburg, (Grout and Eggleston); Lewis Creek, (Faxon).
- P. pectinatus** L. Common.
- P. perfoliatus** L. Slow streams and shallow waters; frequent.
- P. praelongus** Wulf. In deep water; frequent.
- P. pusillus** L. Pools and ditches; common.
- P. pusillus** L., var. *Sturrockii* Benn. Malletts Bay, Lake Champlain, (Griffin).
- P. pusillus** L., var. *tenuissimus* Mertens & Koch. Occasional.
- P. Richardsonii** (Benn.) Rydb. (*P. perfoliatus*, var. *lanceolatus* Robbins). Lake Champlain and its tributaries; frequent.
- P. Robbinsii** Oakes. Common.
- P. rutilus** Wolfgang. Pelot's Bay, N. Hero, (Brainerd).
- P. strictifolius** Benn. (*P. pusillus*, var. *pseudo-rutilus* Benn.). Lake Champlain, (E. & C. E. Faxon); Orwell, (Cushman).
- P. Vaseyi** Robbins. Oozy Pond, Barnet, (Blanchard).
- P. zosterifolius** Schumacher. (*P. compressus* L.). Still and slowly flowing water; common.

ZANNICHELLIA. Horned Pondweed

- Z. palustris** L. Shallow water, South Hero, (Robbins); North Hero, (Pringle); Norwich, (Jesup); Joe's Pond, W. Danville, (Blanchard).

JUNCAGINACEAE. ARROW GRASS FAMILY

SCHEUCHZERIA

- S. palustris** L. Peaty bogs; occasional.

ALISMACEAE. WATER-PLANTAIN FAMILY

ALISMA. Water-plantain

- A. Plantago-aquatica** L. (*A. subcordatum* Raf.). Swales in the lower altitudes; common.

SAGITTARIA. Arrow-head

- S. arifolia** Nutt. (*S. cuneata* Sheldon). Swales and wet shores; frequent along Lake Champlain; Barnard Pond, (Jesup and Sargent); Lake Bomoseen, (Dutton); Hartland, (Whiting); Willoughby Lake, (Kennedy).
- S. graminea** Michx. Low muddy shores of lakes and ponds; frequent.
- S. heterophylla** Pursh. (*S. rigida* Pursh.). Low muddy shores and in shallow water; frequent. Variable. *Forma fluitans* (Engelm.)

Blake. Rhod. 15:159. North Hero, (Brainerd); Lake Champlain, (C. E. Faxon); Swanton and Burlington, (Blake). *Forma rigida* (Pursh.) Blake. Rhod. 15:159. Alburg, (Pringle); Ferrisburg, (Brainerd); Shelburne and Colchester, (Blake).

- S. latifolia* Willd. (*S. variabilis* Engelm.). Wet places; common. *Forma diversifolia* (Engelm.) Robinson. (*S. brevirostra* Mack. & Bush.). With type; occasional. *Forma gracilis* (Pursh.) Robinson. With type; occasional. *Forma obtusa* (Muhl.) Robinson. With type; occasional.

HYDROCHARITACEAE. FROG'S BIT FAMILY

ELODEA. (PHILOTRIA). Water-weed

- E. canadensis* Michx. Slow streams and ponds; frequent.

VALLISNERIA. Tape Grass. Eel Grass

- V. spiralis* L. Quiet, shallow water with sandy bottom; common.

GRAMINEAE. GRASS FAMILY

AGROPYRON

- A. caninum* (L.) Beauv. Awned Wheat Grass. Dry, warm, rocky woodlands of the lower altitudes; frequent.
*A. repens** (L.) Beauv. Couch, Quitch or Quick Grass. Fields and waste places; common.
A. tenerum Vasey. (*A. novae-angliae* Scribn.). Slender Wheat Grass. Willoughby Mt., Smugglers' Notch.

AGROSTIS. Bent Grass

- A. alba* L. White Bent Grass. Meadows and fields; common. *Var. vulgaris** (With.) Thurb. Red Top. Fields; common; dryer situations than type.
A. alba L., var. *aristata* Gray. Upland pastures; frequent.
A. alba L., var. *maritima* (Lam.) G. F. W. Mey. Damp shores, Burlington, (Mrs. N. F. Flynn).
A. borealis Hartm. (*A. canina* var. *alpina* Oakes). Summits of Mt. Mansfield and Camel's Hump, (Pringle).
A. hyemalis (Walt.) BSP. (*A. scabra* Willd.). Hair Grass. Dry ditches and desiccated places; common.
A. perennans (Walt.) Tuckerm. Thin Grass. Moist shaded places; frequent.

ALOPECURUS. Foxtail Grass

- A. geniculatus* L., var. *aristulatus* Torr. (*A. aristulatus* Michx.). Floating Foxtail Grass. Wet meadows; frequent.
*A. pratensis** L. Meadow Foxtail Grass. Introduced in fields and along roadsides; "Bellows Falls," (Carey); Hartland, (Ruggles); Burlington, (Jones); Rutland, (Kirk); Newfane, (Wheeler).

AMMOPHILA

- A. arenaria* (L.) Link. (*A. arundinacea* Host). Beach Grass. Sandy shore of Lake Champlain, Alburg, (Pringle).

ANDROPOGON. Beard Grass

- A. furcatus** Muhl. Forked Beard Grass. Dry, rocky banks of rivers and lakes; occasional in the lower altitudes.
- A. scoparius** Michx. (*Schizachyrium scoparium* [Michx.] Nash.). Broom Beard Grass. Dry, sterile soil; frequent.

ANTHOXANTHUM. Sweet Vernal-grass

- A. odoratum*** L. Moist fields and roadsides; common.

ARISTIDA. Triple-awned Grass

- A. dichotoma** Michx. Poverty Grass. Barren fields; Pownal, (Robbins); New Haven, (Pringle); Essex, (Mrs. N. F. Flynn).
- A. gracilis** Ell. Dry pastures; Vernon, (Grout).

ARRHENATHERUM. Oat-grass

- A. elatius*** (L.) Beauv. (*A. avenaceum* Beauv.). Tall Oat-grass. Charlotte, (Horsford); Burlington, (Jones); Rutland, (Kirk).

AVENA. Oat

- A. fatua*** L. East Wallingford, (Kent).
- A. pubescens*** Huds. Charlotte, (Pringle).
- A. sativa*** L. Cultivated and frequently escapes.

BRACHYELYTRUM

- B. erectum** (Schreb.) Beauv. Moist shaded places; frequent.

BRIZA. Quaking Grass

- B. media*** L. In old meadow, Charlotte, (Pringle); woods, near Evergreen Cemetery, Rutland, (Kirk).

BROMUS. Brome Grass

- B. altissimus** Pursh. Along Hoosic River, North Pownal, (Woodward); Brattleboro, (Wheeler); common along streams in northern part of the state.
- B. arvensis*** L. Windham, (W. H. Blanchard).
- B. ciliatus** L. Wood Chess, Hairy Brome Grass. Moist thickets; common.
- B. erectus*** Huds. Charlotte, (Pringle).
- B. incanus** (Shear.) Hitchc. Along Hoosic River, North Pownal, (Woodward).
- B. inermis*** Leyss. Hungarian Brome Grass. Burlington, (Orton); Colchester, (Griffin); Rutland, (Kirk); Highgate, (Blewitt).
- B. Kalmii** Gray. Wild Chess. Dry woodlands in the lower altitudes of western Vermont; occasional.
- B. purgans** L. Thickets; frequent.
- B. racemosus*** L. Charlotte, (Pringle).
- B. secalinus*** L. Chess. Occasional in fields and along railroads.
- B. tectorum*** L. Charlotte, (Pringle); along railroad, Rutland and Ferrisburg, (Kirk); Burlington, (Mrs. N. F. Flynn).

CALAMAGROSTIS. Reed Bent Grass

- C. canadensis* (Michx.) Beauv. Blue-joint Grass. Marshes and wet places; common.
- C. hyperborea* Lange. Lake Willoughby, (Boott). Specimen in U. S. national herbarium.
- C. inexpansa* Gray. (*C. confinis* Gray). Mt. Mansfield, (Pringle); Lake Willoughby cliffs.
- C. Langedorfi* (Link.) Trin. Mt. Mansfield, (Pringle); Lake Willoughby, (Rusby).
- C. neglecta* (Ehrh.) Gaertner, Meyer & Scherbius. (*C. stricta* Gray's Manual, ed. 6, not Trin.; *C. hyperborea* Lange, var. *americana* Kearney). Lake Willoughby, (Mann); Mt. Mansfield, (Pringle).
- C. Pickeringii* Gray. (*C. breviseta* Scribn.). Vermont, (Pringle). Specimen in U. S. national herbarium.
- C. Pickeringii* Gray, var. *lacustris* (Kearney) Hitchc. (*C. Lapponica* Gray in part; *C. lacustris* [Kearney] Nash). Mt. Mansfield, (Pringle). Specimen in U. S. national herbarium.

CENCHRUS. Sandbur

- C. carolinianus* Walt. Dry sandy soil; local. Colchester and Burlington, (Mrs. N. F. Flynn); Essex, (Griffin); along Connecticut River, Brattleboro, (Grout).

CINNA. Wood Reed Grass

- C. arundinacea* L. Wood Reed Grass. Moist woods; frequent in the lower altitudes.
- C. latifolia* (Trev.) Griseb. (*C. pendula* Trin.). Slender Wood Reed Grass. Moist woods, especially on mountain sides; frequent.

DACTYLIS. Orchard Grass

- D. glomerata** L. Fields, in shade; common.

DANTHONIA. Wild Oat Grass

- D. compressa* Aust. Dry banks and woods; occasional.
- D. spicata* (L.) Beauv. Common Wild Oat Grass. Sterile soil; common.

DESCHAMPSIA

- D. atropurpurea* (Wahlenb.) Scheele. A single specimen collected on Mt. Mansfield by Joseph Torrey, probably before 1853, is in the University of Vermont herbarium. Later botanists have failed to rediscover it.
- D. caespitosa* (L.) Beauv. Tufted Hair Grass. Rocky banks and shores; frequent in the lower altitudes.
- D. flexuosa* (L.) Trin. Common Hair Grass. Dry soil, ascending to highest mountain tops; common.

DIGITARIA. (SYNTHESISMA). Finger Grass

- D. humifusa** Pers. (*S. Ischaemum* [Schreb.] Nash). Small Crab-grass. Occasional in fields and lawns.

- D. sanguinalis*** (L.) Scop. Large Crab-grass. Cultivated fields and waste places; common.

ECHINOCHLOA

- E. crusgalli*** (L.) Beauv. Barnyard Grass. Cultivated ground and moist places; common.

ELYMUS. Wild Rye

- E. australis** Scribn. & Ball. Jamaica, (Dobbin); Essex Junction, (Blake); Townshend, (Wheeler).
E. canadensis L. Nodding Wild Rye. Low thickets and river banks; common. Var. **glaucofolius** (Muhl.) Gray. With type; occasional. Prefers dryer situations.
E. robustus Scribn. & J. G. Sm. Burlington, (Jones).
E. striatus Willd. Slender Wild Rye. Middlebury, (James, Brainerd); ledges of Winooski River, (Pringle); along Otter Creek, Brandon, (Dutton).
E. virginicus L. Wild Rye. Moist thickets along streams in the lower altitudes; frequent. Var. **hirsutiglumis** (Scribn.) Hitchc. (*E. hirsutiglumis* Scribn.). West Haven, (Kirk).

ERAGROSTIS

- E. capillaris** (L.) Nees. Hair Grass. Twin Mt., West Rutland, (Kirk).
E. hypnoides (Lam.) BSP. (*E. reptans* Nees.). Gravelly or sandy banks, in lower altitudes of western Vermont; occasional.
E. megastachya* (Koeler) Link. (*E. major* Host). Stink Grass, Snake Grass. Waste places; Burlington, Woodstock, (Jones); Pownal, Bennington, (Eggleston); Middlebury, (Brainerd); Rutland, (Kirk).
E. pectinacea (Michx.) Steud. Purple Eragrostis. Dry sandy soil; frequent in the lower Connecticut Valley; Townshend, (Wheeler); Essex Junction, (Blake); Stowe, (Mrs. Carrie Straw).
E. pilosa (L.) Beauv. (*E. Purshii* Schrad.). Sandy soil along railroads; frequent.

FESTUCA. Fescue Grass

- F. elatior*** L. Taller or Meadow Fescue. Fields; common.
F. nutans Spreng. Rocky woods in the low altitudes of western Vermont; frequent.
F. octoflora Walt. Slender Fescue. Burlington, (C. H. Knowlton).
F. ovina L. Sheep's Fescue. Frequently introduced, especially in lawns. Var. **brevifolia** (R. Br.) Hack. (*F. brachyphylla* Schultz). Cliffs of Smugglers' Notch; rare. (Grout & Eggleston). Var. **capillata*** (Lam.) Hack. (*F. capillata* Lam.). Introduced; occasional.
F. rubra L. Rocky shores and islands of Lake Champlain; occasional; swamp, Stratton Mountain, (Jones). Var. **subvillosa** Mert. & Koch. In lawn, South Burlington, (Jones).

GLYCERIA. (PANICULARIA). Manna Grass

- G. acutiflora* Torr. Border of pond, Rutland, (Kirk).
- G. borealis* (Nash) Batchelder. Wet places and shallow water; common.
- G. canadensis* (Michx.) Trin. Rattlesnake Grass. Wet places; common.
- G. grandis* Wats. Reed Meadow Grass. Wet soil; common.
- G. nervata* (Willd.) Trin. Fowl Meadow Grass. Wet meadows; common.
- G. pallida* (Torr.) Trin. Pale Manna Grass. Shallow water or wet soil; occasional.
- G. pallida* (Torr.) Trin., var. *Fernaldii* Hitchc. Townshend, (Wheeler).
- G. septentrionalis* Hitchc. Floating Manna Grass. Hartland, (Rugles).
- G. Torreyana* (Spreng.) Hitchc. (*G. elongata* Trin.). Wet woods, especially in the mountains; frequent.

HIEROCHLOE. (SAVASTANA). Holy Grass

- H. alpina* (Sw.) R. & S. Summit of Mt. Mansfield. (Tuckerman and Macrae).
- H. odorata* (L.) Wahlenb. (*H. borealis* R. & S.). Vanilla or Seneca Grass. Moist meadows; occasional.

HOLCUS. (NOTHOHOLCUS)

- H. lanatus** L. Velvet Grass. Fields; Charlotte, (Pringle and Horsford); Peacham, (Blanchard); Windham, (W. H. Blanchard).

HORDEUM. Barley

- H. aegiceras** Nees. Egyptian Barley. Willoughby Lake, (Jones); railroad yard, Burlington, (Jones, Mrs. N. F. Flynn).
- H. jubatum* L. Squirrel-tail Grass. Along railroads and in waste places. Strafford, (Collins); East Wallingford, (Kent); Rutland, (Kirk); Burlington, (Jones); Brandon, (Dutton).

HYSTRIX. Bottle-brush Grass

- H. patula* Moench. (*Asperella Hystrix* Humb.; *H. Hystrix* [L.] Millsp.). Rocky woods; frequent.

LEERSIA. (HOMALOCENCHRUS). Cut Grass

- L. oryzoides* (L.) Sw. Rice Cut Grass. Wet places in the lower altitudes; common.
- L. virginica* Willd. Cut Grass, Scratch Grass. Wet woods of the lower altitudes; frequent.

LEPTOLOMA

- L. cognatum* (Schultes) Chase. Fall Witch Grass. Townshend, (Wheeler); Hartland, (Underwood).

LOLIUM. Darnel

L. perenne* L. Rye-grass, Common Darnel. By roadsides and in meadows; occasional.

L. temulentum* L. Bearded Darnel. Burlington, (Jones); Essex, (Willd.).

MELICA. Melic Grass

M. striata (Michx.) Hitchc. (*Avena striata* Michx.). Purple Oat. Rocky woods; occasional.

MILIUM. Millet Grass

M. effusum L. Cool moist woods; frequent in the mountains.

MOLINIA. (AIRA)

M. caerulea* (L.) Moench. Spreading to woods from cemetery, Rutland, (Kirk).

MUHLENBERGIA. Drop-seed Grass

M. foliosa (R. & S.) Trin. (*M. mexicana* [L.] Trin.). Swampy ground. Willoughby Mt., (Faxon); Townshend, (Wheeler); Sudbury (F. W. Hubby); North Pownal, (W. H. Blanchard); Essex Junction, (Blake). Rhod. 15:160.

M. foliosa (R. & S.) Trin., subsp. *ambigua* (Torr.) Scribn. Lake Champlain, (Faxon).

M. mexicana (L.) Trin. Knot-root Grass. Dry ground and waste places; common.

M. racemosa (Michx.) BSP. (*M. glomerata* Trin.). Wet rocks and marshy places; frequent and variable.

M. Schreberi J. F. Gmel. (*M. diffusa* Schreb.). Drop-seed, Nimble Will. Shaded places in the lower altitudes; occasional.

M. sobolifera (Muhl.) Trin. "Rocky shady hills," (Oakes); Twin Mt., West Rutland, (Kirk).

M. sobolifera (Muhl.) Trin., var. *setigera* Hitchc. West Haven, (Kirk).

M. sylvatica Torr. (*M. umbrosa* Scribn.). Moist banks; occasional.

M. tenuiflora (Willd.) BSP. (*M. Willdenowii* Trin.). Rocky woods; occasional.

ORYZOPSIS. Mountain Rice

O. asperifolia Michx. Woods; common.

O. pungens (Torr.) Hitchc. (*O. canadensis* Torr.). Dry sandy soil in the lower altitudes; occasional.

O. racemosa (Sm.) Ricker. (*O. melanocarpa* Muhl.). Rocky woods; frequent.

PANICUM. Panic Grass

P. agrostoides Spreng. Hartland, (Ruggles); Newfane, (Grout).

P. barbulatum Michx. (*P. dichotomum* L.). Colchester, (Jones).

P. boreale Nash. Woods and fields; frequent on east side of the state; occasional elsewhere.

- P. capillare** L. Old-witch Grass, Tumble-weed. Fields; common.
- P. clandestinum** L. Moist thickets in the lower altitudes; frequent.
- P. columbianum** Scribn. Dry sandy soil; frequent about Burlington.
- P. depauperatum** Muhl. Dry woods and fields in the lower altitudes; occasional.
- P. dichotomum** L. Woods in the lower altitudes; occasional.
- P. huachucae** Ashe. (*P. unciphyllum* of recent Am. auth., not Trin.). Open ground in the lower altitudes; frequent.
- P. huachucae** Ashe, var. *silvicola* Hitchc. & Chase. Woods in the lower altitudes; occasional.
- P. implicatum** Scribn. Wet meadows; frequent in Champlain Valley.
- P. latifolium** L. (*P. macrocarpon* Le Conte). Woodlands in the lower altitudes; common.
- P. Lindheimeri** Nash. Willoughby. (E. & C. E. Faxon).
- P. linearifolium** Scribn. Dry woods and fields in the lower altitudes; common.
- P. miliaceum*** L. European Millet. Burlington, (Brainerd); Rutland, (Kirk); Townshend, (Wheeler).
- P. philadelphicum** Bernh. (*P. minus* Nash). Lake Memphramagog, (Tuckerman).
- P. scoparioides** Ashe. Sandy or gravelly soil; Hartland, (Ruggles).
- P. Scribnerianum** Nash. (*P. scoparium* Wats. & Coult.). Brattleboro, (Grout); Westminster, (Robinson).
- P. sphaerocarpon** Ell. Along railroad, Putney, (W. H. Blanchard).
- P. subvillosum** Ashe. (*P. meridionale* Ashe). Dry woods and sandy ground; Burlington, (Jones); Rutland, (Eggleston).
- P. tennesseense** Ashe. Moist ground in the Champlain Valley; frequent. Hartland, (Ruggles).
- P. tenuetorum** Nash. Moist ground; rare. Burlington, (Jones, Mrs. N. F. Flynn); Salisbury, (Brainerd); Hartland, (Ruggles).
- P. virgatum** L. Switch Grass, Tall Panic Grass. Brattleboro, (M. A. Howe); Ferrisburg, (Kirk); Hartland, (Ruggles).
- P. Wernerii** Scribn. Dry woods and fields; Burlington and Colchester, (Jones).
- P. xanthophysum** Gray. Dry sandy soil; frequent in the lower altitudes.

PASPALUM

- P. Muhlenbergii** Nash. Sandy fields; Bellows Falls, (Carey); Hartland, (Ruggles); Vernon, (Grout); Townshend, (Wheeler).

PHALARIS. Canary Grass

- P. arundinacea** L. Reed Canary-grass. Wet soil; frequent. Var. *picta** L. Ribbon Grass. A frequent garden escape.
- P. canariensis*** L. Canary-grass. Waste places; occasional.

PHLEUM

- P. pratense*** L. Timothy, Herd's Grass. Fields; common.

PHRAGMITES. Reed Grass

- P. communis* Trin. (*P. Phragmites* [L.] Karst). Wild Broom Corn.
Swampy margins of ponds and lakes; occasional.

POA. Meadow Grass. Spear Grass

- P. alsodes* Gray. Moist woods; common.
*P. annua** L. Low Spear Grass. Waysides and fields; common.
*P. compressa** L. Canada Blue Grass, Wire Grass. Dry fields and woods; common.
P. debilis Torr. Dry rocky woods in western Vermont; frequent.
P. laxa Haenke. Summit of Mt. Mansfield, (Robbins).
P. nemoralis L. Rocky woods and cliffs; occasional; very variable.
P. pratensis L. Kentucky Blue-grass, June Grass. Pastures and fields; common.
P. triflora Gilib. (*P. serotina* Ehrh.). False Red Top, Fowl Meadow Grass. Wet soil; common.

SETARIA. (CHAETOCHELOA). Bristly Foxtail Grass

- S. glauca** (L.) Beauv. Foxtail, Pigeon Grass. Fields; common.
S. italica (L.) Beauv., var. *germanica** (Mill) Richter. Italian or German Millet, Hungarian Grass. Occasionally adventive but not persistent.
*S. verticillata** (L.) Beauv. Rough Foxtail Grass. Old garden, Burlington, (Jones).
*S. viridis** (L.) Beauv. Green Foxtail, Bottle Grass. Fields and waste places; common.

SORGHASTRUM. (ANDROPOGON. CHRYSOPOGON)

- S. nutans* (L.) Nash. Indian Grass, Wood Grass. Dry sandy soil in the lower altitudes; occasional.

SPARTINA. Cord or Marsh Grass

- S. Michauxiana* Hitchc. (*S. cynosuroides* Willd. in part). Slough Grass, Tall Marsh Grass. Bellows Falls, (Carey). Shores of Lake Champlain and tributaries; frequent.

SPHENOPHOLIS

- S. nitida* (Spreng.) Scribn. (*Eatonia Dudleyi* Vasey). Colchester, (Torrey).
S. pallens (Spreng.) Scribn. (*Eatonia pennsylvanica* Gray). Moist rocky woods and marshes; frequent.

SPOROBOLUS. Drop-seed. Rush Grass

- S. asper* (Michx.) Kunth. Thompson's Point, Charlotte, (Pringle).
S. neglectus Nash. Dry sandy soil in the lower altitudes; occasional.
S. uniflorus (Muhl.) Scribn. & Merr. (*S. serotinus* Gray). Wet soil; Ripton, (Boyce); Bakersfield, (Pringle); Peacham, (Blanchard); frequent in elevated bogs, Windham County, (Grout).
S. vaginiflorus (Torr.) Wood. Dry soil in the lower altitudes; occasional.

TRIDENS

T. flavus (L.) Hitchc. Tall Red Top. Townshend, (Wheeler).

TRISETUM

T. melicoides (Michx.) Vasey. (*Graphephorum melicoideum* [Michx.] Beauv.). Banks of Winooski River, Colchester and Williston, (Pringle); South Burlington, (Jones).

T. spicatum (L.) Richter. (*T. subspicatum* Beauv., var. *molle* Gray). Narrow False Oat. Dry woods and ledges; occasional.

ZIZANIA. Water or Indian Rice

Z. aquatica L. Wild Rice, Water Oats. In shallow water, Burlington, (Mrs. N. F. Flynn); Lake Memphramagog, (Underwood); West Haven, (Kirk).

Z. palustris L. (*Z. aquatica* Am. auth. not L.). Wild Rice, Water Oats. Marshy borders of Lake Champlain and its tributaries; occasional.

CYPERACEAE. SEDGE FAMILY

CAREX. Sedge

C. aenea Fernald. Cliffs and sand plains; occasional in Rutland and Addison Counties.

C. aestivalis M. A. Curtis. Rocky woods; rare. South Pownal, (J. R. Churchill).

C. albicans Willd. Dry shady ledges; common in western Vermont. Lake Willoughby, (Kennedy); Townshend, (Wheeler).

C. alepocoides Tuckerm. Wet meadows and damp woods; rare. Middlebury, (Brainerd); Burlington, (Hazen); Rutland, (Eggleston).

C. aquatilis Wahlenb. Borders of ponds and rivers; occasional.

C. aquatilis Wahlenb., var. *virescens* Anders. Rutland, (Eggleston); Pownal, (Churchill).

C. arcta Boott. (*C. canescens*, var. *polystachya* Boott). Wet woods; rare. Peacham, (Blanchard); Knight's Island, (Brainerd); Highgate Springs, (Jesup).

C. arctata Boott. Moist woodlands; common.

C. atrata L., var. *ovata* (Rudge) Boott. (*C. atratiformis* Britton). Smugglers' Notch, (Pringle, Burnham).

C. aurea Nutt. Moist meadows; common.

C. Backii Boott. (*C. durifolia* Bailey). Shaded ledges; occasional in the lower altitudes of western Vermont.

C. Bebbii Olney. (*C. tribuloides*, var. *Bebbii* Bailey). Dry low grounds; frequent.

C. Bicknellii Britton. Dry soil; rare. Leicester, (Woodward).

C. bromoides Schkuhr. Bogs and swamps; common.

C. brunnescens Poir. (*C. canescens*, var. *alpicola* Wahlenb.). Common in the mountain woods above 1,800 feet.

C. canescens L. Ripton, (Brainerd).

C. canescens L., var. *disjuncta* Fernald. Wet places; frequent, especially in the mountains.

- C. canescens* L., var. *subulolacea* Laestad. Cold bogs; rare. Mt. Mansfield, (Brainerd); Mud Pond, Wallingford, (Brainerd and Eggleston).
- C. castanea* Wahlenb. Low meadows; local. Pomfret, (Morgan); Barnet, (Blanchard); Middlebury, (Brainerd); Williston, (Mrs. N. F. Flynn); Rutland, (Kirk).
- C. cephaloidea* Dewey. Moist woods; occasional. Middlebury, (Burt); Hartford, (Bates); South Burlington, (Hazen); Essex and Rutland, (Kirk).
- C. cephalophora* Muhl. Dry woods and fields; frequent. Reported in Connecticut Valley north to Hartland.
- C. cherdorrhiza* L. f. Cold bogs; rare. Bristol Pond, (Pringle); "Eastern Vermont," (Congdon); Perch Pond, Pownal, (J. R. Churchill); Colchester, (Jones, Grout).
- C. communis* Bailey. (*C. pedicellata* Britton). Dry fields; common.
- C. comosa* Boott. (*C. Pseudo-Cyperus*, var. *americana* Hochst.). Swamps; frequent.
- C. conoidea* Schkuhr. Moist meadows in the lower altitudes; occasional.
- C. Crawfordii* Fernald. (*C. scoparia*, var. *minor* Boott). Open sterile soil; frequent. Var. *vigens* Fernald. Middlebury, (Brainerd); Rutland, (Eggleston); St. Johnsbury and Burlington, (Hazen).
- C. crinita* Lam. Swales and along brooks; common.
- C. crinita* Lam., var. *gynandra* (Schwein.) Schwein. & Torr. (*C. gynandra* Schwein.). Wet soil, especially in the mountains; frequent.
- C. crinita* Lam., var. *simulans* Fernald. Mt. Mansfield, (Brainerd); Ripton, (E. F. Williams).
- C. cristata* Schwein. (*C. tribuloides*, var. *cristata* Bailey; *C. cristatella* Britton). Wet grounds in low places; occasional.
- C. debilis* Michx., var. *Rudgei* Bailey. (*C. tenuis* Rudge; *C. flexuosa* Muhl.). Frequent in moist sterile soil in the mountains. Colchester, (Hazen).
- C. deflexa* Hornem. Abby Pond, Ripton, (Brainerd); Groton, (Pringle); St. Johnsbury, (Eggleston and Isabel Paddock); East Wallingford, (Kent); Peacham, (Blanchard).
- C. Deweyana* Schwein. Dry woods; common.
- C. diandra* Schrank. (*C. teretiuscula* Gooden.). Bogs; occasional.
- C. diandra* Schrank, var. *ramosa* (Boott) Fernald. (*C. teretiuscula*, var. *ramosa* Boott; *C. prairea* Dewey). Bristol Pond, (Brainerd); Peacham, (Blanchard); Rutland, (G. H. Ross); Brandon, (Dutton).
- C. digitalis* Willd. Dry open woods in the lower altitudes; frequent.
- C. eburnea* Boott. (*C. setifolia* Britton). On dry shaded limestone; frequent.
- C. exilis* Dewey. Peat bogs. Bristol, (Pringle); Peacham, (Blanchard); Franklin, (Underwood).
- C. festucacea* Schkuhr. (*C. straminea*, var. *festucacea* Tuckerm.). Dry soil in the lower altitudes; occasional.

- C. festucacea* Schkuhr, var. *brevlor* (Dewey) Fernald. (*C. straminea*, var. *brevior* Dewey). Gardner's Island, Lake Champlain, (Brainerd).
- C. filiformis* L. (*C. lasiocarpa* Ehrh.). Peaty borders of ponds; frequent.
- C. flava* L. Low meadows; common.
- C. flava* L., var. *elatior* Schlecht. (*C. lepidocarpa* Tausch). Flat sandy borders of ponds; frequent in western Vermont.
- C. flava* L., var. *rectirostra* Gaudin. (*C. flava*, var. *graminis* Bailey). Margins of springs and ponds at higher altitudes than type; common.
- C. foenea* Willd. Dry woods of the lower altitudes; often on rocks; rare. Var. *perplexa* Bailey. Dry copses; Middlebury, (Brainerd); Fairlee, (Blanchard); Rutland, (Eggleston); St. Johnsbury, (Hazen).
- C. folliculata* L. Cold swamps; Burlington, (Torrey, Mrs. N. F. Flynn); Stratton and Marlboro Ponds, (Grout); Sunderland, (Eggleston); Athens, (Wheeler).
- C. formosa* Dewey. Moist meadows; Middlebury, (Brainerd); Shelburne, (Mrs. N. F. Flynn).
- C. glaucodes* Tuckerm. Middletown Springs, (Carpenter).
- C. Goodenowii* J. Gay. (*C. rigida*, var. *Goodenowii* Bailey). Wet meadows, Peacham, (Blanchard).
- C. gracillima* Schwein. Low meadows; common.
- C. granularis* Muhl. Moist meadows of the lower altitudes; common.
- C. granularis* Muhl., var. *Haleana* (Olney) Porter. (*C. Shriveri* Britton). Burlington, (Hazen).
- C. Grayii* Carey. (*C. Asa-Grayi* Bailey). Swales, along rivers and lakes of the Champlain Valley; rare.
- C. grisea* Wahlenb. Along brooks in thickets in the lower altitudes; occasional.
- C. Hitchcockiana* Dewey. Rich woods; occasional in western Vermont. Pomfret, (A. R. Morse).
- C. Houghtonii* Torr. Dry sandy banks; Norwich, (E. A. Edmunds); Rutland, (Eggleston); Burlington, (Mrs. N. F. Flynn).
- C. hystericina* Muhl. Wet meadows; common. Var. *Cooleyi* Dewey. Wetter places than type; occasional.
- C. intumescens* Rudge. Wet woods and swamps; common.
- C. intumescens* Rudge, var. *Fernaldii* Bailey. Similar situations as the type; occasional.
- C. lanuginosa* Michx. (*C. filiformis* L., var. *latifolia* Boeckl.). Swales and low meadows of the lower altitudes; frequent.
- C. laxiculmis* Schwein, var. *copulata* (Bailey) Fernald. Moist copses in the lower altitudes; occasional.
- C. laxiflora* Lam. Rich woods and meadows; occasional.
- C. laxiflora* Lam., var. *blanda* (Dewey) Boott. (*C. blanda* Dewey). Moist meadows; frequent.

- C. laxiflora* Lam., var. *gracillima* Boott. West Haven, (Kirk and Ross); Middlebury, (Brainerd).
- C. laxiflora* Lam., var. *latifolia* Boott. (*C. albursina* Sheldon). Moist rich woods; frequent.
- C. laxiflora* Lam., var. *patulifolia* (Dewey) Carey. (*C. anceps* Muhl.). Rich woods; frequent.
- C. laxiflora* Lam., var. *varians* Bailey. Copses and meadows; common.
- C. lenticularis* Michx. Sandy borders of ponds and lakes; rare.
- C. leptalea* Wahl. Wet woods and bogs; frequent.
- C. leptonervia* Fernald. (*C. laxiflora* Lam., var. *leptonervia* Fernald). Rhod. 16: 213. New Haven and Middlebury, (Brainerd); Mt. Mansfield, (Churchill); Mt. Willoughby, (E. S. Hoar); Townshend, (Wheeler).
- C. limosa* L. Bogs; occasional.
- C. livida* (Wahlenb.) Willd. Bogs north of Bristol Pond, (Pringle).
- C. longirostris* Torr. (*C. Sprengelli* Dewey). Shady ledges and banks of the lower altitudes; frequent.
- C. lupuliformis* Sartwell. (*C. lupulina* Muhl., var. *polystachya* Schwein. & Torr.). Marshes along Lake Champlain; frequent. Hartland, (Kirk).
- C. lupulina* Muhl. Swamps and ditches of the lower altitudes; common.
- C. lupulina* Muhl., var. *pedunculata* Dewey. North Hero, (Brainerd); Newfane, (Grout); Middletown Springs, (Carpenter); Burlington, (Hazen).
- C. lurida* Wahlenb. Wet meadows; common.
- C. lurida* Wahlenb., var. *gracilis* (Boott) Bailey. (*C. Baileyi* Britt.). Bogs in the mountains; frequent.
- C. Michauxiana* Boeckl. (*C. abacta* Bailey). Bogs and lake borders at high altitudes; Sterling Pond, (Pringle); frequent in the elevated bogs of Windham County, (Grout); Fifield Pond, Wallingford, (Eggleston); also at Lake of the Clouds, Mt. Mansfield, from seed sown there by Mr. Pringle.
- C. mirabilis* Dewey. (*C. normalis* Mackenzie). Moist shaded places; occasional. Var. *perlonga* Fernald. Little Notch, Bristol, (Brainerd).
- C. Muhlenbergii* Schkuhr. Dry sand, near Fort Ethan Allen, (Hazen). Var. *enervis* Boott. Townshend, (Wheeler).
- C. novae-angliae* Schwein. Shady knolls; frequent in the mountains.
- C. Oederi* Retz., var. *pumila* (Cosson & Germain) Fernald. (*C. flava* L., var. *viridula* Bailey). Shores of lakes and rivers. Lake Fairlee, (Blanchard); Pomfret, (Morgan); White River, (Flint); Shelburne, (F. A. Ross); Willoughby, (Kennedy).
- C. oligocarpa* Schkuhr. Dry copses; Middlebury, (Brainerd); North Hero, (Cushman).
- C. oligosperma* Michx. Bogs; Peacham, (Blanchard); Stratton, (Grout); Sunderland, (Eggleston); Colchester, (Blake).
- C. pallescens* L. Low meadows; common.

- C. pauciflora* Lightf. Sphagnum bogs; rare.
- C. paupercula* Michx., var. *irrigua* (Wahlenb.) Fernald. (*C. magellanica* Gray's Manual, ed. 6, not Lam.). Cold bogs; occasional.
- C. paupercula* Michx., var. *pallens* Fernald. Cold bogs; rare.
- C. pedunculata* Muhl. Dry woods of the lower altitudes; frequent.
- C. pennsylvanica* Lam. Shady hillsides of the lower altitudes; common.
- C. pennsylvanica* Lam., var. *lucorum* (Willd.) Fernald. Damper places than type and less common. Middlebury and Burlington, (Brainerd); Pownal, (Churchill); Fair Haven, (Eggleston); Rutland, (Kirk).
- C. plantaginea* Lam. Rich woods; frequent.
- C. platyphylla* Carey. Shady banks; common.
- C. polygama* Schkuhr. (*C. fusca* All.; *C. Buxbaumii* Wahl.). Bogs; Burlington, (Torrey); Fairlee, (Jesup); Mendon, (Eggleston).
- C. prasina* Wahlenb. Springy bogs in woods of the lower altitudes; occasional.
- C. Pseudo-Cyperus* L. Swamps; Knight's Island, (Brainerd); Barnet, (Blanchard); Fair Haven, (Kirk); Shelburne, (Blake).
- C. pubescens* Muhl. (*C. hirtifolia* Mackenzle). Damp thickets of the lower altitudes; occasional.
- C. retrorsa* Schwein. Swamps; common.
- C. retrorsa* Schwein., var. *Hartii* (Dewey) Gray. Marshes; occasional.
- C. rigida* Good., var. *Bigelowii* (Torr.) Tuckerm. (*C. concolor* R. Br.). Alpine summits of Green Mountains.
- C. riparia* W. Curtis. Swales; occasional.
- C. rosea* Schkuhr. Rich dry woods; common.
- C. rosea* Schkuhr., var. *minor* Boott. Willoughby Lake, (William Boott); North Hero, (Cushman).
- C. rosea* Schkuhr., var. *radiata* Dewey. Shady knolls; frequent.
- C. rostrata* Stokes. (*C. utriculata* Boott, var. *minor* Boott). Marshes; occasional.
- C. rostrata* Stokes, var. *utriculata* (Boott) Bailey. (*C. utriculata* Boott). Marshes; frequent.
- C. scabrata* Schwein. Springy bogs in woods; frequent.
- C. Schweinitzii* Dewey. Swamps; local. Pownal, (Dewey); Salisbury, (Brainerd); Manchester, (Mary A. Day); North Dorset, (Mrs. N. F. Flynn).
- C. scirpoides* Michx. Alpine cliffs, Willoughby Lake, Smugglers' Notch; also Mt. Equinox, Manchester, (Mary A. Day); Mt. Horrid, Rochester, (Dutton).
- C. scirpoides* Schkuhr. (*C. interior* Bailey). Boggy meadows: common.
- C. scoparia* Schkuhr. Moist meadows; common. Var. *condensa* Fernald. Similar situations as the type; frequent. Var. *moniliformis* Tuckerm. Burlington, (Hazen); Dame Island, (Brainerd).
- C. setacea* Dewey. Sudbury, (Brainerd).

- C. setacea* Dewey, var. *ambigua* (Barrat) Fernald. (*C. xanthocarpa* Bicknell; *C. annectens* Bicknell). Moist meadows; common in Addison County, (Brainerd); Rutland, (Kirk).
- C. siccata* Dewey. Sandy shore of Lake Champlain north of Lake View Cemetery, Burlington.
- C. sparganoides* Muhl. Rich moist woods; occasional.
- C. stellulata* Good. (*C. sterilis* Am. auth. not Willd.; *C. Leersii* Willd.). Wet meadows and pastures, especially in the mountains.
- C. stellulata* Good., var. *angustata* Carey. (*C. sterilis*, var. *angustata* Bailey). Mostly in shade at high altitudes.
- C. stellulata* Good., var. *cephalantha* (Bailey) Fernald. (*C. Leersii* Willd.). Bogs; Fort Ethan Allen pond and Brandon, (Kirk).
- C. stellulata* Good., var. *excelsior* (Bailey) Fernald. Wet margins of ponds and brooks; occasional.
- C. stipata* Muhl. Swales; common.
- C. straminea* Willd. Dryish copses and fields; common.
- C. straminea* Willd., var. *echinodes* Fernald. Dame Island, North Hero and Burlington, (Brainerd).
- C. stricta* Lam. Swales and marshes; common.
- C. stricta* Lam., var. *angustata* (Boott) Bailey. Swales; Manchester, (Mary A. Day).
- C. stricta* Lam., var. *curtissima* Peck. Essex Junction, (Brainerd); Fair Haven, (Kirk).
- C. stricta* Lam., var. *decora* Bailey. (*C. Haydeni* Dewey). Barnet, (Blanchard); East Wallingford, (Kent); Rutland, (Kirk).
- C. tenella* Schkuhr. (*C. disperma* Dewey). Cold swamps; frequent.
- C. tenniflora* Wahlenb. Quaking bog, Bristol Pond, (Pringle); Cedar swamp, Fair Haven, (Oakes, Eggleston); Salem and Burlington, (Robbins); Peacham, (Blanchard); West Derby, (Underwood).
- C. tinctoria* Fernald. (*C. mirabilis* Dewey, var. *tinctoria* Fernald). Rhod. 15: 186. St. Johnsbury, (Hazen); Hartland, (Ruggles).
- C. torta* Boott. Along mountain streams; frequent.
- C. tribuloides* Wahlenb. Open swales; frequent. Var. *turbata* Bailey. Burlington, (Hazen).
- C. tribuloides* Wahlenb., var. *reducta* Bailey. (*C. projecta* Mackenzie). Moist mountain woods; occasional.
- C. triceps* Michx., var. *hirsuta* (Willd.) Bailey. (*C. complanata* Torr.). Moist fields of western Vermont; occasional. Winhall, (Carpenter and Wheeler).
- C. trichocarpa* Muhl. Marshes; Pownal Center, (Carpenter); West Haven, (Kirk and Ross).
- C. trisperma* Dewey. Cold bogs in shade; frequent.
- C. Tuckermani* Dewey. Swales and marshes; frequent.
- C. typhinioides* Schwein. (*C. typhina* Michx.). Low borders of streams and lake margins in western Vermont; occasional.
- C. umbellata* Schkuhr. Rocky hills and dry knolls of the lower altitudes; frequent.

- C. umbellata* Schkuhr, var. *brevirostris* Boott. (*C. abdita* Bicknell). Snake Mt., (Brainerd).
- C. vaginata* Tausch. (*C. saltuensis* Bailey). Deep swamps; Sutton, (Pringle).
- C. varia* Muhl. Dry woods; Weeping Rocks, Pownal, (Eggleston and Andrews); Colchester, (Brainerd); Burlington, (Pringle); North Pownal, (Eggleston); Hartland, (Ruggles).
- C. vesicaria* L. Swales; occasional. Var. *distenta* Fries. Knight's Island, (Brainerd). Var. *jejuna* Fernald. Swales; occasional. Var. *monile* (Tuckerm.) Fernald. (*C. monile* Tuckerm.). Swales; common.
- C. virescens* Muhl. (*C. virescens* Muhl., var. *costata* Dewey). Moist copses; Middlebury, (Brainerd); Rutland, (Kirk).
- C. virescens* Muhl., var. *Swanii* Fernald. (*C. virescens* Gray's Man. ed. 6, not Muhl.; *C. Swanii* [Fernald] Mackenzie). Moist pastures; common.
- C. vulpinoidea* Michx. Moist pastures; common.
- C. arcata* x *castanea* Bailey. One plant, Middlebury, (Brainerd).
- C. lurida* x *impulma* Bailey. North Hero, (Morong).
- C. stricta* x *torta* Fernald. Mt. Mansfield, (Kennedy).

CLADIUM. (MARISCUS). Twig Rush

- C. mariscoides* (Muhl.) Torr. Low borders of ponds; occasional.

CYPERUS. Galingale

- C. aristatus* Rottb. (*C. inflexus* Muhl.) Wet sandy soil of the lower altitudes; frequent.
- C. dentatus* Torr. Sandy shores of ponds in the lower altitudes; occasional.
- C. diandrus* Torr. Low ground; occasional.
- C. esculentus* L. Alluvial soil of the lower altitudes; occasional.
- C. filiculmis* Vahl., var. *macilentus* Fernald. Dry sands of the lower altitudes; common.
- C. Houghtonii* Torr. Shifting sand; Fairlee Lake, (Jesup); Colchester, (Mrs. N. F. Flynn); Castleton, (Brainerd); Essex Junction, (Blake).
- C. rivularis* Kunth. (*C. diandrus* Torr., var. *castaneus* Torr.). Wet soil of the lower altitudes; common.
- C. strigosus* L. Moist soil of the lower altitudes; frequent. *Forma capitatus* (Boeckl.) Blake. Rhod. 15: 200. Cobble Hill, Milton, and Swanton, (Blake).
- C. strigosus* L., var. *compositus* Britton. Essex Junction, Burlington, and Swanton, (Blake).

DULICHIMUM

- D. arundinaceum* (L.) Britton. (*D. spathaceum* Pers.). Borders of ponds; common.

ELEOCHARIS. Spike-rush

- E. acicularis* (L.) R. & S. Pools and shores below high water mark; common.
- E. diandra* C. Wright. Wet sands of Connecticut River, Westminster, (Brainerd); Burlington, (Mrs. N. F. Flynn).
- E. intermedia* (Muhl.) Schultes. In mire or wet sands; occasional.
- E. obtusa* (Willd.) Schultes. Muddy places; common.
- E. olivacea* Torr. Soft mire; Bristol Pond, (Pringle); Abby Pond, Ripton, and Lake Dunmore, (Brainerd); Kenney Pond, Newfane, (Grout).
- E. ovata* (Roth.) R. & S. In soft black mire, inlet of Abby Pond, Ripton, and Lake Dunmore, (Brainerd); Spectacle Pond, Wallingford, (Eggleston).
- E. palustris* (L.) R. & S. Low borders of ponds in the lower altitudes; occasional. Var. *calva* (Torr.) Gray. Stony clay shores of Lake Champlain; occasional. Var. *glaucescens* (Willd.) Gray. Moist grassy places; common. Var. *major* Sonder. (var. *vicens* Bailey). Rhod. 11: 39. Low sandy shores of Lake Champlain; frequent.
- E. tenuis* (Willd.) Schultes. Wet meadows and lake borders; common.

ERIOPHORUM. Cotton-grass

- E. callitrix* Cham. (*E. vaginatum* Am. auth., not L.). Peat bogs; occasional.
- E. gracile* Roth. Bogs; Middlebury, Ripton, (Brainerd); Ryegate, (Blanchard); Willoughby Lake, (A. W. Cheever).
- E. tenellum* Nutt. (*E. gracile*, var. *paucinervium* Engelm.). Bogs; occasional.
- E. virginicum* L. Peat bogs; frequent.
- E. viridi-carinatum* (Engelm.) Fernald. (*E. polystachion* of most Am. auth.). Springy places and bogs; common.

FIMBRISTYLIS

- F. autumnalis* (L.) R. & S. Lily Pond, Vernon, (Grout).

RYNCHOSPORA. Beak-rush

- R. alba* (L.) Vahl. Bogs; frequent.
- R. capillacea* Torr. Willoughby Mountain, (Jesup); Hartford, (Morgan).
- R. fusca* (L.) Ait. f. Low grounds; Thetford Center, (Blanchard); Wells River, (Horsford).
- R. glomerata* (L.) Vahl. Moist soil of the lower altitudes; occasional.

SCIRPUS. Bulrush. Club Rush

- S. americanus* Pers. (*S. pungens* Vahl.). Chair-maker's Rush. Sandy borders of lakes and rivers in the lower altitudes; frequent.
- S. atrocinctus* Fernald. Wet meadows; common, especially in the mountains. Var. *brachypodus* Fernald. Bogs, generally at high altitudes; occasional.

- S. atrovirens* Muhl. Wet meadows. The typical form is rare. Var. *pycnocephalus* Fernald. Hartland, (Dutton); Essex Junction, Burlington, St. Albans, Swanton, (Blake).
- S. caespitosus* L. Moist rocks of alpine summits; local. Mt. Equinox, Sandgate, (Burnham and Dobbin).
- S. cyperinus* (L.) Kunth. Wool Grass. Wet meadows; Middlebury, (Brainerd); Rutland, (Kirk). Var. *Andrewsii* Fernald. Middlebury, (Brainerd); Wallingford, (Eggleston).
- S. cyperinus* (L.) Kunth. var. *pellus* Fernald. Wet places; common. Var. *condensatus* Fernald. Middlebury and Ripton, (Brainerd); Williston, (Blake).
- S. debilis* Pursh. Wet soil; Norwich, (Jesup); Westminster, (Brainerd).
- S. flaviatilis* (Torr.) Gray. River Bulrush. Marshy borders of bays and tributaries of Lake Champlain; frequent.
- S. georgianus* Harper. Wet places; common.
- S. heterochaetus* Chase. Sheltered shores of northern Lake Champlain; occasional.
- S. hudsonianus* (Michx.) Fernald. (*Eriophorum alpinum* L.). Cold bogs, especially in the mountains; common.
- S. lineatus* Michx. Moist clay soil; Middlebury, (Brainerd); Bristol, (Dike); Ferrisburg, (Blake).
- S. occidentalis* (Wats.) Chase. Sandy shores of Lake Champlain; frequent. Previously confused with *S. validus* Vahl.
- S. pauciflorus* Lightf. (*Eleocharis pauciflora* Link). Wet soil; Lyndon, (Congdon); Willoughby Mountain, (Tuckerman).
- S. Peckii* Britton. Moist meadows and bogs in the mountains; occasional. Colchester, (Mrs. N. F. Flynn).
- S. pedicellatus* Fernald. Swales in the lower altitudes; common. Var. *pullus* Fernald. Swales and boggy margins of ponds; occasional.
- S. planifolius* Muhl. Mount Philo, Charlotte, (Pringle); North Pownal, (Mrs. N. F. Flynn).
- S. rubrolineatus* Fernald. Wet meadows; common, especially in the mountains. Var. *confertus* Fernald. Goshen, (Dutton); Stratton, (Wheeler).
- S. Smithii* Gray. Keeler's Bay, Ferrisburg, (E. Faxon); mouth of Winooski River, (Grout and Tracy). Var. *setosus* Fernald. In muck, Brandon, (Kirk and Dutton).
- S. subterminalis* Torr. Grout Pond, Stratton, (Grout); Lake Dunmore, (Brainerd).
- S. sylvaticus* L. Townshend, (Wheeler).
- S. Torreyi* Olney. Muddy shores, Fort Cassin, Ferrisburg, (Brainerd); Swanton, (Blewitt); Barnet, (Blanchard); ponds of Windham County, (Grout); Burlington, (Blake).
- S. validus* Vahl. (*S. lacustris* mostly of Am. auth., not L.). Great Bulrush. In shallow water; common.

STENOPHYLLUS

- S. capillaris* (L.) Britton. (*Fimbristylis capillaris* Gray). Dry sands of the lower altitudes; rare.

ARACEAE. ARUM FAMILY

ACORUS. Sweet Flag, Calamus

- A. Calamus* L. Marshes of the lower altitudes; common.

ARISAEMA. Indian Turnip

- A. Dracontium* (L.) Schott. Green Dragon. Low grounds; "Shoreham," (Robbins); Weybridge, (Brainerd); Rutland, (Kirk); West Haven, (Mrs. M. C. Munson).
A. triphyllum (L.) Schott. Indian Turnip, Jack-in-the-pulpit. Rich woods; common.

CALLA. Water Arum

- C. palustris* L. Wild Calla. Cold bogs and marshes; frequent.

PELTANDRA. Arrow Arum

- P. virginica* (L.) Kunth. (*P. undulata* Raf.). Shallow water; Colchester Pond, (Robbins); Middlebury, (Brainerd); Bristol Pond, (Pringle); Lake Bomoseen marshes, (Eggleston); West Haven, (Kirk).

SYMPLOCARPUS. (SPATHYEMA). Skunk Cabbage

- S. foetidus* (L.) Nutt. Wet places; occasional. Common around Burlington. Stratton, (W. H. Blanchard).

LEMNACEAE. DUCKWEED FAMILY

LEMNA. Duckweed

- L. minor* L. Lesser Duckweed. Still water; occasional.
L. trisulca L. Duck's-meat. Still water; frequent in marshes bordering Lake Champlain.

SPIRODELA

- S. polyrrhiza* (L.) Schleid. Greater Duckweed. Stagnant pools; common.

ERIOCAULACEAE. PIPEWORT FAMILY

ERIOCAULON. Pipewort

- E. septangulare* Withering. (*E. articulatum* [Huds.] Morong in part). Rhod. 11: 40. Borders of ponds and lakes; frequent.

XYRIDACEAE. YELLOW-EYED GRASS FAMILY

XYRIS. Yellow-eyed Grass

- X. caroliniana* Walt. Wet borders of ponds; "Brattleboro," (Frost); Newfane, (Grout); Lily Pond, Athens and Jamaica, (Wheeler).
X. montana Ries. Cold Pond, Jamaica, (Dobbin and Wheeler).

COMMELINACEAE. SPIDERWORT FAMILY

COMMELINA. Day-flower

C. communis L. Occasional as a garden escape.

TRADESCANTIA. Spiderwort

T. plicata Lehm. Hartland, (Underwood).

PONTEDERIAEAE. PICKEREL-WEED FAMILY

HETERANTHERA. Mud Plantain

H. dubia (Jacq.) MacM. (*H. graminea* Vahl). Water Star Grass.
Ponds and streams of the Champlain Valley; frequent.

PONTEDERIA. Pickerel-weed

P. cordata L. Borders of ponds and slow streams in the lower altitudes; frequent.

JUNCACEAE. RUSH FAMILY

JUNCUS. Rush. Bog Rush

J. acuminatus Michx. Sharp-fruited Rush. Wet meadows; Essex, (Jones).

J. alpinus Vill. Willoughby Lake, (Eggleston).

J. alpinus Vill., var. *fuscescens* Fernald. Knight's Island, (Brainerd).

J. alpinus Vill., var. *insignis* Fries. Wet gravelly shores of Lake Champlain; Knight's Island and Shelburne, (Pringle); Burlington, (Mrs. N. F. Flynn).

J. articulatus L. Jointed Rush. Wet grounds; occasional.

J. articulatus L., var. *obtusatus* Engelm. Manchester, (Mary A. Day).

J. brachycephalus (Engelm.) Buchenau. (*J. canadensis* J. Gay, var. *brachycephalus* Engelm.). Moist sandy soil; occasional.

J. brevicaudatus (Engelm.) Fernald. (*J. canadensis* J. Gay, var. *brevicaudatus* Engelm.). Common, especially in the mountains.

J. bufonius L. Toad Rush. Low ground; common.

J. bufonius L., var. *congestus* Wahlb. Burlington, (Mrs. N. F. Flynn).

J. canadensis J. Gay. Borders of ponds in the lower altitudes; frequent.

J. Dudleyi Wiegand. Damp soil; frequent.

J. effusus L., var. *Pylaei* (Laharpe) Fernald & Wiegand. Rhod. 12: 92.
Bog Rush. Marshy ground; common.

J. effusus L., var. *solutus* Fernald & Wiegand. Rhod. 12: 90. Essex, Burlington, and Underhill, (Blake).

J. filiformis L. Sandy shores of northern Lake Champlain and on mountain summits; occasional.

J. Gerardi Loisel. Black Grass. Marshy meadow near railroad station, New Haven, (Brainerd). Perhaps introduced with salt hay used in packing.

J. Greenii Oakes & Tuckerm. Newfane, (M. A. Howe).

- J. marginatus** Rostk. Newfane, (M. A. Howe); Putney, (W. H. Blanchard); Rutland, (Eggleston and Kirk); Townshend, (Wheeler).
J. nodosus L. Knotted Rush. Wet meadows; common.
J. pelocarpus Mey. Shores of ponds in the lower altitudes; occasional.
J. secundus Beauv. Twin Mt., West Rutland, (Eggleston).
J. tenuis Willd. Slender Rush, Yard Rush. Wet ground; common.
J. tenuis Willd., var. **Williamsii** Fernald. Sandy soil; Rutland, (Eggleston); Willoughby Lake, (Kennedy); Brandon, (Dutton).
J. Torreyi Coville. Along railroad track, Rutland, (Kirk); roadside, Charlotte, (Blake).
J. trifidus L. Summit of Mt. Mansfield, (Robbins); Camel's Hump, (Tuckerman and Macrae); Mount Horrid, Rochester, (Dutton and Kirk).

LUZULA. (JUNCOIDES). Wood Rush

- L. campestris** (L.) DC., var. **multiflora** (Ehrh.) Celak. (*L. campestris* of Am. auth. not DC.). Dry woods and fields; frequent.
L. parviflora (Ehrh.) Desv. (*L. spadicea*, var. *melanocarpa* Mey.). Wet places at high altitudes; occasional.
L. saltuensis Fernald. (*L. vernalis* Gray's Manual, ed. 6, not DC.; *J. carolinæ* [S. Wats.] Kuntze). Hairy Wood Rush. Woods and banks of the lower altitudes; frequent.
L. spicata (L.) DC. Smugglers' Notch, (Pringle); rare.

LILIACEAE. LILY FAMILY

ALLIUM. Onion

- A. canadense** L. Wild Garlic. Wet meadows, West Rutland, (Kirk).
A. Schoenoprasum* L. Chives. Garden escape, Willoughby Lake, (Kennedy).
A. Schoenoprasum L., var. **sibiricum** (L.) Hartm. (*A. sibiricum* L.). Moist rocky shores of the Connecticut River. Windsor, (Leland); Hartland, (Eggleston).
A. tricoccum Alt. Wild Leek. Rich woods; frequent.

ASPARAGUS. Asparagus

- A. officinalis*** L. A frequent escape from gardens.

CLINTONIA

- C. borealis** (Alt.) Raf. Yellow Clintonia. Cool moist woods; common, especially in the mountains.

CONVALLARIA. Lily of the Valley

- C. majalis** L. Persistent in old dooryards; thickly covers an area of about six square rods in a mucky bog at Waltham, (Ruth B. Fisher).

ERYTHRONIUM. Dog's-tooth Violet

E. americanum Ker. Yellow Adder's Tongue. Rich copses and woodlands; common.

HEMEROCALLIS. Day Lily

*H. flava** L. Yellow Day Lily, Lemon Lily. A garden escape, (W. H. Blanchard).

*H. fulva** L. Common Day Lily. Roadside escape from gardens; frequent.

LILIUM. Lily

L. canadense L. Wild Yellow Lily, Meadow Lily. Moist meadows of the lower altitudes; common.

L. philadelphicum L. Wood Lily, Wild Orange-red Lily. Sandy open woodlands of the lower altitudes; common.

*L. tigrinum** Ker. Tiger Lily. Roadside escape from gardens.

MAIANTHEMUM. (UNIFOLIUM)

M. canadense Desf. Wild Lily of the Valley, Two-leaved Solomon's Seal. Woods; common.

MEDEOLA. Indian Cucumber-root

M. virginiana L. Rich moist woods; common.

OAKESIA. (UVULARIA)

O. sessilifolia (L.) Wats. Bellwort. Moist woodlands; common.

ORNITHOGALUM. Star of Bethlehem

*O. umbellatum** L. Garden escape; Brattleboro, (W. H. Blanchard); Bradford, (Alice E. Bacon).

POLYGONATUM. Solomon's Seal

P. biflorum (Walt.) Ell. Small Solomon's Seal. Wooded hillsides; common.

P. commutatum (R. & S.) Dietr. (*P. giganteum* Dietr.). Great Solomon's Seal. Meadows and river banks; Hartford, (Ward); Manchester and Vernon, (Grout); Fairlee, (Jesup and Sargent); Pownal, (Eggleston and Andrews); Stowe, (Mrs. Carrie E. Straw).

SMILACINA. (VAGNERA). False Solomon's Seal

S. racemosa (L.) Desf. False Spikenard. Moist copses; common.

S. stellata (L.) Desf. Star-flowered Solomon's Seal. Wet fields and wooded swamps; frequent.

S. trifolia (L.) Desf. Three-leaved Solomon's Seal. Cold sphagnum bogs; occasional.

SMILAX. Green-brier

S. herbacea L. Carrion-flower. River banks and moist thickets of the lower altitudes; frequent.

STREPTOPUS. Twisted-stalk

- S. amplexifolius** (L.) DC. Wet mountain woods; frequent.
S. roseus Michx. Cold damp woods; common.

TOFIELDIA. (TRIANTHA). False Asphodel

- T. glutinosa** (Michx.) Pers. Quechee Gulf, (Leland); roadside, North Bridgewater, (Kirk).

TRILLIUM. Wake-robin. Birth-root

- T. cernuum** L. Nodding Trillium. Moist woods of the lower altitudes; occasional.
T. erectum L. Purple Trillium. Rich woods; common.
T. grandiflorum (Michx.) Salisb. White Trillium. Rich moist woods of western Vermont; common in Champlain Valley.
T. undulatum Willd. (*T. erythrocarpum* Michx.). Painted Trillium. Cool moist woods; frequent.

UVULARIA. Bellwort

- U. grandiflora** Sm. Large-flowered Bellwort. Rich woods of the lower altitudes; common.
U. perfoliata L. Rich woods; West Rutland, rare: Pownal, abundant, (Eggleston).

VERATRUM. False Hellebore

- V. viride** Alt. American White Hellebore, Indian Poke. Wet meadows and swamps; common.

ZIGADENUS. (ANTICLEA). Death Camass

- Z. chloranthus** Richards. (*Z. elegans* of auth., not Pursh). Bluffs of Lake Champlain, Ferrisburg, (Brainerd).

IRIDACEAE. IRIS FAMILY**IRIS. Fleur-de-lis**

- I. pseudacorus*** L. Yellow Iris. Garden escape. Bank of Winoski River, Essex, (F. A. Ross); Leicester, (Dutton).
I. versicolor L. Wild Iris, Blue Flag. Wet meadows; common

SISYRINCHIUM. Blue-eyed Grass

- S. angustifolium** Mill. Moist meadows; common.
S. atlanticum Bicknell. Stratton, above 2,000 feet, (Grout); Wardsboro, (Underwood); Hartland, (Nancy Darling).
S. mucronatum Michx. Hartland, (Underwood).

ORCHIDACEAE. ORCHIS FAMILY**APLECTRUM. Putty-root. Adam-and-Eve**

- A. hyemale** (Muhl.) Torr. Rich woods in low altitudes of western Vermont; local, St. Johnsbury, (Inez A. Howe).

ARETHUSA

- A. bulbosa* L. Sphagnum bogs; occasional.

CALOPOGON. (LIMODORUM)

- C. pulchellus* (Sw.) R. Br. (*C. tuberosum* L.). Grass Pink. Bogs; occasional.

CALYPSO. (CYTHEREA)

- C. bulbosa* (L.) Oakes. (*C. borealis* Salisb.). Cold cedar swamps of northern counties; rare. Leicester, (Dutton) is most southern Vermont station.

CORALLORRHIZA. Coral Root

- C. maculata* Raf. (*C. multiflora* Nutt.). Large Coral Root. Dry woods; occasional.
- C. edenterhiza* Nutt. Coral Root, Dragon's Claw. Bellows Falls, (Carey), specimen in the herbarium of the Boston Society of Natural History; Pease Mountain, Charlotte, (Pringle); Pownal, (Eggleston); Hartland, (Underwood).
- C. trifida* Chatelain. (*C. innata* R. Br.; *C. Corallorrhiza* [L.] Karst.). Early Coral Root. Swamps and damp woods; frequent.

CYPRIPEDIUM. Lady's Slipper. Moccasin Flower

- C. acaule* Ait. (*Fissipes acaulis* [Ait.] Small). Stemless or Pink Lady's Slipper. Woods and swamps; frequent.
- C. arietinum* R. Br. Ram's Head Lady's Slipper. Rocky woods and swamps; local and rare.
- C. hirsutum* Mill. (*C. spectabile* Salisb.; *C. reginae* Walt.). Showy Lady's Slipper. Cold swamps; occasional.
- C. parviflorum* Salisb. Smaller Yellow Lady's Slipper. Bogs and low woods; frequent.
- C. parviflorum* Salisb., var. *pubescens* (Willd.) Knight. (*C. pubescens* Willd.). Large Yellow Lady's Slipper. Rich moist woods; frequent.

EPIPACTIS. (GOODYERA, PERAMIMUM). Rattlesnake Plantain

- E. pubescens* (Willd.) A. A. Eaton. (*G. pubescens* R. Br.). Downy Rattlesnake Plantain. Dry woods at low altitudes; occasional.
- E. repens* (L.) Crantz, var. *ophioides* (Fernald) Eaton. (*G. repens*, var. Fernald; *P. ophioides* [Fernald] Rydb.). Lesser Rattlesnake Plantain. Cold mossy spruce woods; frequent. Rare in swamps at low altitudes.
- E. tessellata* (Lodd.) A. A. Eaton. (*G. tessellata* Lodd.). Rattlesnake Plantain. Cold moist woods at high altitudes; occasional.

HABENARIA. Rein Orchis, Fringed Orchis

- X *H. Andrewsii* White. (*H. lacera* x *psycodes*). Bogs; Pownal, (Andrews); Rutland, (Kirk); Hartland, (Nancy Darling).

- H. blephariglottis** (Willd.) Torr. (*Blephariglottis blephariglottis* [Willd.] Rydb.). White Fringed Orchis. North Troy, (Carey); specimen in the herbarium of the Boston Society of Natural History; Smugglers' Notch, (Eggleston); Burlington, (Torrey); Johnson, (Grout); Franklin, (Underwood); North Pownal, (Grace G. Niles).
- H. bracteata** (Willd.) R. Br. (*Coeloglossum bracteatum* [Willd.] Parl.). Long-bracted Orchis. Damp woods and meadows; frequent.
- H. ciliaris** (L.) R. Br. (*Blephariglottis ciliaris* [L.] Rydb.). Yellow Fringed Orchis. Bellows Falls, (Carey); specimen in the herbarium of the Missouri Botanical Garden; reported by A. A. Eaton.
- H. clavellata** (Michx.) Spreng. (*H. tridentata* Hook.; *Gymnadeniopsis clavellata* [Michx.] Rydb.). Small Wood Orchis. Bogs and wet borders of ponds; occasional.
- H. dilatata** (Pursh.) Gray. (*Limnorchis dilatata* [Pursh.] Rydb.). White Bog Orchis. Cold bogs; frequent at high altitudes.
- H. dilatata** (Pursh.) Gray, var. *media* (Rydb.) Ames. Cold bogs; rare.
- H. fimbriata** (Ait.) R. Br. (*Blephariglottis grandiflora* [Bigel.] Rydb.). Large Purple Fringed Orchis. Cold mountain woods and meadows; occasional.
- H. flava** (L.) Gray. (*H. virescens* Spreng.; *Perularia flava* [L.] Farwell). Small Pale Green Orchis. Moist soil of the lower altitudes; local.
- H. Hookeri** Torr. (*H. Hookeriana* Gray; *Lysias Hookeriana* [Gray] Rydb.). Dry woods; occasional.
- H. hyperborea** (L.) R. Br. (*Limnorchis hyperborea* [L.] Rydb.). Tall Green Orchis. Bogs and cold woods; frequent.
- H. lacera** (Michx.) R. Br. (*Blephariglottis lacera* [Michx.] Farwell). Ragged Fringed Orchis. Moist ground; occasional.
- H. leucophaea** (Nutt.) Gray. (*Blephariglottis leucophaea* [Nutt.] Farwell). Moist pasture, St. Johnsbury, (Inez A. Howe).
- H. macrophylla** Goldie. (*H. orbiculata* Torr. in part; *Lysias orbiculata* [Pursh] Rydb.). Dry mountain woods; occasional.
- H. obtusata** (Pursh.) Richards. (*Lysiella obtusata* [Pursh.] Rydb.). Cold mountain woods; occasional.
- H. orbiculata** (Pursh.) Torr. (*Lysias orbiculata* [Pursh.] Rydb.). Large Round-leaved Orchis. Cold rich woods; occasional.
- H. psycodes** (L.) Sw. (*Blephariglottis psycodes* [L.] Rydb.). Smaller Purple Fringed Orchis. Wet meadows and bogs; frequent.

LIPARIS. Twayblade

- L. hillifolia** (L.) Richard. Large Twayblade. Rich woods; occasional.
- L. Loeselii** (L.) Richard. Fen Orchis. Moist fields; frequent.

LISTERA. (OPHRYS). Twayblade

- L. auriculata** Wiegand. Lyndon, (Congdon).
- L. convallarioides** (Sw.) Torr. Cold mountain bogs and brooksides; rare.

- L. cordata** (L.) R. Br. Heart-leaved Twayblade. Sphagnum bogs and mossy mountain woods; frequent.

MICROSTYLIS. (MALAXIS). Adder's Mouth

- M. monophyllos** (L.) Lindl. White Adder's Mouth. Swamps and mountain cliffs; rare.
- M. unifolia** (Michx.) BSP. (*M. ophiglossoides* Eaton). Green Adder's Mouth. Open woods; occasional.

ORCHIS

- O. rotundifolia** Banks. Cold cedar swamps of northern Vermont; rare. Monkton, Bristol, and Starksboro, (Pringle).
- O. spectabilis** L. (*Galeorchis spectabilis* [L.] Rydb.). Showy Orchis. Rich moist woods of the lower altitudes; common.

POGONIA

- P. affinis** Aust. (*Isotria affinis* [Aust.] Rydb.). Small Whorled Pogonia. Burlington, one plant, (Mrs. Holt).
- P. ophiglossoides** (L.) Ker. Rose Pogonia, Snake-mouth. Bogs; frequent.
- P. trianthophora** (Sw.) BSP. (*P. pendula* Lindl.; *Triphora trianthophora* [Sw.] Rydb.). Nodding Pogonia. Dry woodlands. Fair Haven, (Chandler); Newfane, (Howe and Grout); Westminster, Putney, (W. H. Blanchard).
- P. verticillata** (Willd.) Nutt. (*Isotria verticillata* [Willd.] Raf.). Whorled Pogonia. Colchester, (Robbins, Torrey); Pownal, (Andrews, Grace G. Niles); Burlington, (F. A. Ross).

SPIRANTHES. (IBIDIUM). Ladies' Tresses

- S. cernua** (L.) Richard. Nodding Ladies' Tresses. Wet soil; common. Var. *ochroleuca* (Rydb.) Ames. Hartland, (Nancy Darling).
- S. gracilis** (Bigel.) Beck. Slender Ladies' Tresses. Sandy woods and plains; occasional.
- S. lucida** (H. H. Eaton) Ames. (*S. latifolia* Torr.; *I. plantagineum* [Raf.] House). Wet gravelly shores; occasional.
- S. Romanzoffiana** Cham. (*I. strictum* [Rydb.] House.). Bogs and cold moist soil; occasional.

SALICACEAE. WILLOW FAMILY

POPULUS. Poplar. Aspen

- P. alba*** L. White Poplar, Silver-leaved Poplar. Frequent in cultivation and an occasional escape.
- P. balsamifera** L. Balsam Poplar, Tacamahac. Borders of streams and swamps; frequent.
- P. canadensis*** Ait. Balm of Gilead. Occasional in cultivation and sometimes spontaneous.

- P. deltoides** Marsh. Cottonwood, Necklace Poplar. Borders of low-land streams and lakes; frequent in western Vermont and in the Connecticut Valley as far north as Brattleboro.
- P. grandidentata** Michx. Large-toothed Aspen. Rich woods; frequent.
- P. nigra** L., var. *italica** Du Roi. (*P. dilatata* Ait.). Lombardy Poplar. Frequent in cultivation and spreading from the root. Only staminate trees occur.
- P. tremuloides** Michx. American Aspen, Trembling Poplar, Popple. Woods; common.

SALIX. Willow. Osier

- S. alba*** L. White Willow. Burlington, (Blake). Var. *caerulea** (Sm.) Koch. Cultivated and sometimes spontaneous. Barre, (Eunice P. Smith). Var. *vitellina** (L.) Koch. Frequent in cultivation and as an escape by streams.
- S. balsamifera** Barratt. (*S. pyrifolia* Anders.). Mt. Mansfield, (Pringle); Long Pond, Westmore, (E. Faxon); Elmore Mountain, (Grout). Frequent about Willoughby Lake, (Kennedy).
- S. candida** Flügge. Sage Willow, Hoary Willow. Cold bogs; rare.
- S. cordata** Muhl. Heart-leaved Willow. Low wet soil; common.
- S. discolor** Muhl. Glaucaous Willow, Pussy Willow. Wet soil; common. Var. *eriocephala* (Michx.) Anders. South Burlington, (Kirk and Jones, Blake). Var. *prinoides* (Pursh.) Anders. Johnson, (Grout).
- S. fragilis*** L. Crack Willow. Common in cultivation and frequent as an escape.
- S. humilis** Marsh. Prairie Willow. Sandy barrens; frequent.
- S. longifolia** Muhl. (*S. fluviatilis* auth., not Nutt.; *S. interior* Rowlee). Sand Bar Willow. Shores of Lake Champlain and the lower Connecticut River; rare.
- S. lucida** Muhl. Shining Willow. Moist banks; frequent. Var. *augustifolia* Anders. Burlington, (Blake).
- S. nigra** Marsh. Black Willow. Banks of streams and ponds; common. Var. *falcata* (Pursh.) Torr. With type; frequent.
- S. pedicellaris** Pursh. Bog Willow. Peat bog, Bristol, (Eggleston and Dike).
- S. pedicellaris** Pursh., var. *hypoglauca* Fernald. (*S. pedicellaris* Gray's Manual, ed. 6, in part). Rhod. 11: 161. Cold bogs; Burlington, (Robbins); Rutland, (Ross); Brandon and Leicester, (Dutton); Colchester, (Grout).
- S. pellita** Anders. Banks of Connecticut River, Bloomfield, (Eggleston).
- S. petiolaris** Sm. Slender Willow. Swamps and shores of Lake Champlain; occasional. Willoughby Lake, (Annie Lorenz).
- S. phyllifolia** L. Lake of the Clouds, Mt. Mansfield, (Pringle).
- S. purpurea*** L. Purple Willow. Occasional as an escape. Once cultivated for basket rods.

- S. restrata* Richards. (*S. Bebbiana* Sargent). Beaked Willow. Borders of thickets; common.
- S. sericea* Marsh. Silky Willow. In swamps and along streams; frequent.
- S. Uva-ursi* Pursh. Summit of Mt. Mansfield, (Robbins).
- S. discolor* x *humilis*. Johnson, (Grout).
- S. fragilis** x *alba*, var. *vitellina** Johnson, (Grout).
- S. lucida* x *sericea*. Rutland, (Kirk).
- S. nigra* x *sericea*. Rutland, (Kirk).
- S. sericea* x *cordata*. Johnson, (Grout).

MYRICACEAE. SWEET GALE FAMILY

MYRICA

- M. asplenifolia* L. (*Comptonia peregrina* [L.] Coulter). Sweet Fern. Dry sterile soil of the lower altitudes; common.
- M. Gale* L. Sweet Gale. Swamps and borders of ponds; frequent.

JUGLANDACEAE. WALNUT FAMILY

CARYA. (HICORIA). Hickory

- C. alba* (L.) K. Koch. Mocker Nut, White Heart Hickory. Rocky pasture, Burlington, (Burns).
- C. cordiformis* (Wang.) K. Koch. (*C. amara* Nutt.). Bitternut Hickory. In moist soil; frequent in the lower altitudes of western Vermont and known in Connecticut Valley as far north as Hartland.
- C. glabra* (Mill.) Spach. (*C. porcina* Nutt.). Pignut. West Castleton, Pownal, (Eggleston); Marsh Hill, Ferrisburg, (Brainerd).
- C. ovata* (Mill.) K. Koch. (*C. alba* Nutt.). Shellbark Hickory. Rich soil; frequent in the lower altitudes west of the Green Mountains; known in the Connecticut Valley as far north as Bellows Falls. Often cultivated; therefore native habitat is sometimes difficult to determine.

JUGLANS. Walnut

- J. cinerea* L. Butternut. Rocky hillsides; frequent.

BETULACEAE. BIRCH FAMILY

ALNUS. Alder

- A. crispa* (Ait.) Pursh. (*A. viridis*, Gray's Manual, ed. 6, in part, not DC.; *A. Alnobetula* Am. auth. in part, not K. Koch). Green Alder. Higher mountain tops; common.
- A. crispa* (Ait.) Pursh, var. *mollis* Fernald. Rhod. 15: 44. Downy Green Alder. Rocky shores of Connecticut River; occasional. Burlington Bay, (Mrs. N. F. Flynn); Jamaica, (Dobbin).
- A. incana* (L.) Moench. Speckled or Hoary Alder. Borders of streams; common.

- A. rugosa** (Du Roi) Spreng. (*A. serrulata* Willd.). Smooth Alder.
Moist soil of the lower altitudes; frequent.
- A. rugosa x incana.** Burlington, (Jones and Eggleston).

BETULA. Birch

- B. alba** L. Paper, Canoe or White Birch. Mt. Mansfield, (Blake).
- B. alba** L., var. **cordifolia** (Regel) Fernald. Rocky mountain slopes; occasional.
- B. alba** L., var. **minor** (Tuckerm.) Fernald. One tree, Fairfield Pond, (Blake).
- B. alba** L., var. **papyrifera** (Marsh.) Spach. (*B. papyrifera* Marsh.). Woodlands; common.
- B. lenta** L. Cherry, Sweet or Black Birch. Rich woodlands of the lower altitudes; frequent in western Vermont and known in the Connecticut Valley as far north as Hanover, N. H. Willoughby Lake, (Kennedy).
- B. lutea** Michx. f. Yellow or Gray Birch. Rich cool soils; frequent, especially on mountain sides.
- B. pendula** Roth. (*B. caerulea* Blanchard). White or Canoe Birch. Stratton, Windham, Worcester and Elmore, (W. H. Blanchard).
- B. populifolia** Marsh. White, Gray or Old Field Birch. Frequent in the Champlain Valley. Occurs in every town in Windham County, in Stratton up to 2,000 feet altitude, (W. H. Blanchard); Lemington, Essex County, (Eggleston).

CARPINUS. Hornbeam. Ironwood

- C. caroliniana** Walt. American Hornbeam, Blue or Water Beech. Near streams of the lower altitudes; frequent.

CORYLUS. Hazelnut. Filbert

- C. americana** Walt. Hazelnut. Thickets of the lower altitudes; occasional. Known in Connecticut Valley as far north as Hartford, (Jesup).
- C. rostrata** Alt. Beaked Hazelnut. Dry thickets; common.

OSTRYA. Hop Hornbeam. Ironwood

- O. virginiana** (Mill.) K. Koch. American Hop Hornbeam, Leverwood. Rich woods; common.

FAGACEAE. BEECH FAMILY

CASTANEA. Chestnut

- C. dentata** (Marsh.) Borkh. Frequent in lower Connecticut Valley and in southwestern Vermont. In Connecticut Valley not known in native habitat much north of Bellows Falls. Small groves occur at West Rutland, (Eggleston), and at Leicester, (Dutton); and a few trees at Burlington, (Jones); at Colchester, (Griffin); and at Stowe, (Mrs. Carrie E. Straw).

FAGUS. Beech

F. grandifolia Ehrh. (*F. ferruginea* Ait.). Rich uplands; common.

QUERCUS. Oak

Q. alba L. White Oak. Common west of the Green Mountains. In the Connecticut Valley north to Wells River.

Q. bicolor Willd. (*Q. platanoidea* Sudw.). Swamp White Oak. Low moist soil; frequent in the Champlain Valley, especially near the Lake.

Q. bicifolia Wang. (*Q. nana* Sargent). Bear or Black Scrub Oak. Dry sandy soil; Rutland, (Pursh. in 1806); "Bellows Falls," (Carey); Brattleboro, (Grout); Westminster and West Dummerston, (W. H. Blanchard).

Q. macrocarpa Michx. Bur Oak, Over-cup or Mossy-cup Oak. Rich soil; occasional in the Champlain Valley, more common in Addison County.

Q. Muhlenbergii Engelm. Yellow Oak, Chestnut Oak. Gardiner's Island, Ferrisburg, (Pringle); Mallets Head, Colchester, (Griffin).

Q. prinoides Willd. Scrub Chestnut Oak. Dry hillsides; "Pownal," (Robbins); North Pownal, (Eggleston); Snake Mountain, (Brainard).

Q. prinus L. Chestnut Oak. Dry rocky hillsides in western Vermont; frequent from Charlotte to Pownal.

Q. rubra L. Red Oak. Common below 1,000 feet altitude. Var. *ambigua* (Michx. f.) Fernald. (*Q. borealis* Michx. f.). Gray Oak. Rocky woods, Burlington, (Burns).

Q. velutina Lam. Quercitron, Yellow-barked or Black Oak. Dry light soil; frequent in western Vermont and in the Connecticut Valley north to Bellows Falls.

Q. macrocarpa x *alba*. Charlotte, (Pringle).

Q. prinus x *alba*. Monkton, (Pringle).

URTICACEAE. NETTLE FAMILY

BOEHMERIA. False Nettle

B. cylindrica (L.) Sw. Moist shady ground in the lower altitudes; common.

CANNABIS. Hemp

*C. sativa** L. Waste places; occasional.

CELTIS. Nettle Tree, Hackberry

C. occidentalis L. Sugarberry. River banks and intervals; rare.

HUMULUS. Hop

*H. japonicus** Sieb. & Zucc. Japanese Hop. Waste places; Burlington, (Jones); Brattleboro, (Anne S. Angell); Bellows Falls, (W. H. Blanchard).

H. Lupulus L. Common Hop. Occasional by waysides as an escape from cultivation.

LAPORTEA. Wood Nettle

L. canadensis (L.) Gaud. (*Utricastrum divaricatum* [L.] Kuntze). Moist rich woods; common.

MORUS. Mulberry

M. alba* L. White Mulberry. Often planted and occasionally escaped. Middlebury, (Brainerd); Burlington, (Mrs. N. F. Flynn).

M. rubra L. Red Mulberry. Rich woods; rare. Pownal, (Oakes); North Pownal, (Eggleston).

PARIETARIA. Pellitory

P. pennsylvanica Muhl. Rocky banks and cliffs; occasional in western Vermont. Jamaica, (Wheeler).

PILEA. Richweed. Clearweed

P. pumila (L.) Gray. Cool moist woods in the lower altitudes; common.

ULMUS. Elm

U. americana L. American or White Elm. Moist soil; common.

U. campestris* L. English Elm. Escaped to roadside, Colchester, (Mrs. N. F. Flynn).

U. fulva Michx. Slippery or Red Elm. Rich rocky woods; occasional.

U. racemosa Thomas. (*U. Thomasi* Sarg.). Cork Elm. Limestone soils, western Vermont; rare.

URTICA. Nettle

U. gracilis Ait. Slender or Tall White Nettle. Fence rows and moist ground; common.

U. Lyallii Wats. (*U. gracilis*, Gray's Manual, ed. 6, in part). Alluvial thickets and waste places; occasional.

U. urens* L. Small or Dwarf Nettle. Waste places; Barnet, (Blanchard); Royalton, (Ward).

SANTALACEAE. SANDALWOOD FAMILY

COMANDRA. Bastard Toad Flax

C. livida Richards. Summit of Mt. Mansfield under stunted balsams, (Pringle).

C. Richardsiana Fernald. Dry sandy or gravelly soil along Lake Champlain; frequent.

C. umbellata (L.) Nutt. Dry thickets of the lower altitudes in western Vermont; frequent.

LORANTHACEAE. MISTLETOE FAMILY

ARCEUTHOBIUM. (RAZOUMOFSKYA)

- A. pusillum** Peck. Dwarf Mistletoe. Parasitic on spruces and tamaracks, mainly in swamps; occasional. Rhod. 2: 1.

ARISTOLOCHACEAE. BIRTHWORT FAMILY

ASARUM. Wild Ginger

- A. canadense** L. Rich rocky woods; common.

POLYGONACEAE. BUCKWHEAT FAMILY

FAGOPYRUM. Buckwheat

- F. esculentum*** Moench. (*F. Fagopyrum* [L.] Karst). Buckwheat. Persisting from cultivation.
- F. tartaricum*** (L.) Gaertn. India Wheat. Persisting in cultivated fields.

POLYGONELLA. Jointweed

- P. articulata** (L.) Meisn. Coast Jointweed or Knot Grass. Sandy shore of Lake Champlain, Colchester, (Pringle, Mrs. N. F. Flynn); Brattleboro, 1844, (T. W. Higginson); Highgate, (Blewitt); Milton, (Griffin).

POLYGONUM. Knotweed

- P. acre** HBK., var. *leptostachyum* Meisn. (*Persicaria punctata*, var. *leptostachyum* Small). Water Smartweed. Wet meadows of the lower altitudes of western Vermont; occasional.
- P. amphibium** L. (*Persicaria amphibia* [L.] S. F. Gray). Water Persicaria. Margins of ponds and slow streams; frequent. Var. *Hartwrightii* (Gray) Bissell. (*Persicaria Hartwrightii* Gray). Marshes; occasional. Forma *terrestre* (Loers) Blake. Colchester, Fairfield and Swanton, (Blake).
- P. arifolium** L. (*Tracaulon arifolium* [L.] Raf.) Halberd-leaved Tearthumb. Low grounds; frequent in Champlain Valley. East Clarendon, (Kirk); Pownal, (Eggleston).
- P. aviculare** L. Knotgrass, Doorweed. Dooryards and roadsides; common.
- P. aviculare** L., var. *angustissimum* Meisn. (*P. neglectum* Besser). Sandy beaches; occasional.
- P. aviculare** L., var. *vegetum* Ledeb. In moister situations than type; frequent.
- P. Carey** Olney. (*Persicaria Carey* [Olney] Greene). Brattleboro, (Frost, Grout); Newfane, (Grout); Cavendish Gorge, (Fernald); Westminster, (W. H. Blanchard); Stowe, (Mrs. Carrie E. Straw).
- P. ciliinode** Michx. (*Tinlaria ciliinode* [Michx.] Small). Fringed Black Blindweed. Rocky copses; frequent.

- P. Convolvulus*** L. (*Tiniaria Convolvulus* [L.] Webb & Moq.). Black Bindweed, Wild Buckwheat. Cultivated ground; common.
- P. Douglasii** Greene. Dry soil; occasional in the Champlain Valley.
- P. erectum** L. Erect Knotweed. Dooryards and roadsides; occasional.
- P. Hydropiper** L. Common Smartweed or Water Pepper, Bite-tongue. (*Persicaria Hydropiper* [L.] Opir.). Moist places; common.
- P. hydropiperoides** Michx. (*Persicaria hydropiperoides* [Michx.] Small). Mild Water Pepper. Wet places and shallow water in the lower altitudes; occasional.
- P. lapathifolium** L. (*P. incarnatum* of auth.; *Persicaria lapathifolia* [L.] S. F. Gray). Dock-leaved or Pale Persicaria. Alluvial soil; common. Var. *nodosum* (Pers.) Weinmann. Frequent.
- P. Muhlenbergii** (Meisn.) Wats. (*Persicaria Muhlenbergii* [S. Wats.] Small). Muddy or dry places of the lower altitudes of western Vermont; frequent.
- P. orientale*** L. (*Persicaria orientalis* [L.] Spach.). Prince's Feather. Occasionally persisting about gardens.
- P. pennsylvanicum** L. (*Persicaria pennsylvanica* [L.] Small). Pink Knotweed. Moist soil; common.
- P. Persicaria*** L. (*Persicaria Persicaria* [L.] Small). Lady's Thumb. Waste places; a common weed.
- P. sagittatum** L. (*Tracaulon sagittatum* [L.] Small). Arrow-leaved Tear-thumb. Low ground; common.
- P. scandens** L. (*P. dumetorum* L., var. *scandens* Gray; *Tiniaria scandens* [L.] Small). Climbing False Buckwheat. Moist thickets; frequent.
- P. tomentosum** Schrank. (*Persicaria tomentosa* [Schrank] Bicknell). Field, Rutland, (Kirk).
- P. virginianum** L. (*Tovara virginiana* [L.] Raf.). Moist thickets of the lower altitudes; occasional.
- P. viviparum** L. (*Bistorta vivipara* [L.] S. F. Gray). Mt. Mansfield, (Pringle).

RUMEX. Dock. Sorrel

- R. Acetosa*** L. Garden Sorrel. Charlotte, (Pringle); Burlington, (Jones); Woodstock, (Mrs. Clara Mack).
- R. Acetosella*** L. Field or Sheep Sorrel. Fields; common.
- R. Britannica** L. Great Water Dock. Wet places in the low altitudes of western Vermont; frequent.
- R. crispus*** L. Yellow Dock, Curled Dock. Fields and waste places; common.
- R. elongatus*** Guss. Fields; common.
- R. mexicanus** Meisn. Waste places; Colchester, (Sprague); Burlington and Rutland, (Mrs. N. F. Flynn); St. Albans, (Blake); Fairhaven, (Brainerd).
- R. obtusifolius*** L. Bitter Dock. Fields and waste places; common.
- R. Patientia*** L. Patience Dock. Cultivated fields and roadsides; occasional; apparently becoming more common.

- R. verticillatus* L. Swamp Dock. Swamps; common in the western counties.

CHENOPODIACEAE. GOOSEFOOT FAMILY

ATRIPLEX. Orach

- A. patula* L., var. *hastata* (L.) Gray. (*A. hastata* L.). Spreading Orach. Waste places, especially along railways; naturalized; occasional. Var., *littoralis* (L.) Gray. (*A. hastata* L.). Sandy shores; occasional.

CHENOPODIUM. Pigweed. Goosefoot

- C. album** L. Lamb's Quarters, Pigweed. Fields; common. Var., *viride** (L.) Moq. Common.
- C. ambrosioides** L. Mexican Tea. Charlotte, (Pringle); Colchester, (Mrs. N. F. Flynn); St. Albans, (Blewitt).
- C. Botrys** L. Jerusalem Oak, Feather Geranium. Waste places; becoming common.
- C. capitatum* (L.) Asch. (*Blitum capitatum* L.). Strawberry Blite. Dry rich ground; apparently indigenous in places, occasionally introduced.
- C. glaucum** L. Oak-leaved Goosefoot. Railroad yards, Burlington, Bennington, Ferrisburg, Rutland, St. Albans.
- C. hybridum* L. Maple-leaved Goosefoot. Shady ledges and waste places; frequent.
- C. urticum** L. City or Upright Goosefoot. Lumber yards, Burlington, (Howe); West Haven, (Kirk and Ross).

KOCHIA

- K. Scoparia** (L.) Schrad. Mexican Fire Plant. Frequently spontaneous and sometimes persisting.

SALSOLA. Saltwort

- S. Kali* L., var. *tenuifolia** G. F. W. Mey. Russian Thistle. Of recent introduction along railroads; Burlington, (Mrs. N. F. Flynn); Colchester, (Jones); Rutland, (Kirk); Essex Junction and Swanton, (Blake).

AMARANTHACEAE. AMARANTH FAMILY

ACNIDA. Water Hemp

- A. tuberculata* Moq. Shady banks of slow streams or bays, Champlain Valley; frequent.

AMARANTHUS. Amaranth

- A. blitoides* Wats. Prostrate Amaranth. Yards and waste places; occasional, becoming more common.
- A. graecizans* L. (*A. albus* L.). Tumble Weed. Waste places; a recently introduced weed in railroad yards and gardens. Burling-

ton, Charlotte, (Pringle); Bennington, (Eggleston); Rutland, (Kirk).

- A. hybridus*** L. Green Amaranth, Pigweed. Old garden, Peacham, (Blanchard); along railroad, Rutland, (Kirk).
- A. caudatus*** L. Purple Amaranth. Shelburne, as a garden weed, (Pringle); West Windsor, (Blanchard).
- A. retroflexus*** L. Green Amaranth, Pigweed. Rich cultivated ground; common.
- A. spinosus*** L. Spiny Amaranth. Cultivated field, Burlington, (Mrs. Jane Walker).

PHYTOLACCACEAE. POKEWEED FAMILY

PHYTOLACCA. Pokeweed

- P. decandra** L. (*P. americana* L.). Common Poke or Scape, Pigeon Berry. Pastures and fields; occasional.

NYCTAGINACEAE. FOUR-O'CLOCK FAMILY

OXYBAPHUS

- O. floribundus** Choix. (*Allionia nyctaginea* Michx.). Along railroad, Swanton, (Blake).
- O. nyctagineus** (Michx.) Sweet. St. Johnsbury, (Inez A. Howe).

ILLECEBRACEAE. KNOTWORT FAMILY

ANYCHIA. Forked Chickweed

- A. canadensis** (L.) BSP. (*A. capillacea* DC.). Dry open woodlands; Pownal, (Robbins, Eggleston); West Rutland, (Eggleston); Proctor, (Kirk); Bellows Falls, (W. H. Blanchard).

AIZOACEAE. CARPET WEED FAMILY

MOLLUGO. Indian Chickweed

- M. verticillata*** L. Carpet Weed. Sandy banks and waste places; frequent.

CARYOPHYLLACEAE. PINK FAMILY

AGROSTEMMA. Corn Cockle

- A. Githago*** L. (*Lychnis Githago* Scop.). Corn Cockle, Rose Pink. Fields; occasional.

ARENARIA. Sandwort

- A. groenlandica** (Retz.) Spreng. Mountain Sandwort. Common on rocks at summits of Mt. Mansfield and Camel's Hump.
- A. lateriflora** L. Blunt-leaved Sandwort. (*Moehringia lateriflora* Fenzl.). Moist banks and shores of the lower altitudes; occasional.
- A. macrophylla** Hook. (*Moehringia macrophylla* [Hook.] Torr.). Large-leaved Sandwort. Abundant on ledges above Proctorsville, (Eggleston).

- A. serpyllifolia** L. Thyme-leaved Sandwort. Dry rocky places; frequent.
- A. stricta* Michx. (*A. Michauxii* Hook. f.). Rock Sandwort. Cliffs and headlands of the lower altitudes; occasional.
- A. verna* L., var. *propinqua* (Richards.) Fernald. Smugglers' Notch, (Pringle).

CERASTIUM. Mouse-ear Chickweed

- C. arvense* L. Field Mouse-ear Chickweed. Dry rocky places of the lower altitudes; occasional.
- C. nutans* Raf. (*C. longipedunculatum* Muhl.). Nodding Chickweed, Powder Horn. Thin soil on ledges, west of the Green Mountains; occasional.
- C. vulgatum** L. Common Mouse-ear Chickweed. Fields; common.

DIANTHUS. Pink

- D. Armeria** L. Deptford Pink. Fields; Castleton, (Ross).
- D. barbatus** L. Sweet William. Garden escape; Rutland, (Eggleston); Stowe, (Wild); Manchester, (Miss Mary A. Day); Essex, (Mrs. N. F. Flynn).
- D. deltoides** L. Maiden Pink. Roadsides and cemeteries; occasional.
- D. plumarius** L. Grass Pink. Garden escape; Manchester, (Mrs. Mary C. Munson); East Wallingford, (Kent).

GYPSOPHILA

- G. muralis** L. Low Gypsophila, Mist. Burlington, (Jones); Colchester, (Mrs. N. F. Flynn).
- G. paniculata** L. Baby's Breath. Stowe, (Mrs. Carrie E. Straw).

LYCHNIS. Campion

- L. alba** Mill. (*L. vespertina* Sibth.). White Campion, Evening Lychnis. Weed in fields; occasional.
- L. chalcedonica** L. Scarlet Lychnis. Peacham, (Blanchard); Barnet, (Jesup and Sargent).
- L. coronaria** (L.) Desr. Mullein Pink. Rocky pastures; abundant on Round Mountain, Shrewsbury, (Eggleston); Jamaica, (Bates).
- L. dioica** L. (*L. diurna* Sibth.). Day-blooming Lychnis. Brattleboro, (Bates and Jones); Burlington, (Morse); Colchester, (Mrs. N. F. Flynn).
- L. Flos-cuculi** L. Ragged Robin. Weed, roadsides and meadows, Craftsbury, (Jones); field, Rutland, (Kirk).

SAGINA. Pearlwort

- S. decumbens* (Ell.) T. & G. Small-flowered Pearlwort. Brattleboro, (Grout).
- S. procumbens* L. Pearlwort. Springy places; occasional.

SAPONARIA

- S. officinalis** L. Soapwort, Bouncing Bet. Waste places; common.

- S. Vaccaria*** L. (*Vaccaria Vaccaria* Britton). Cow-herb. Vernon, (Grout); Westmore, (J. R. Churchill); Pownal, (Eggleston); Rutland, (Kirk); Burlington, (Mrs. N. F. Flynn).

SILENE. Catchfly. Campion

- S. antirrhina** L. Sleepy Catchfly. Dry soil in the lower altitudes; frequent.
- S. Armeria*** L. Sweet William Catchfly. Underhill, (Jones); Burlington, (Mrs. N. F. Flynn).
- S. dichotoma*** Ehrh. Forked Catchfly. Townshend, (Blanchard).
- S. latifolia*** (Mill.) Britten & Rendle. (*S. Cucubalus* Wibel). Bladder Campion. Roadsides and fields; frequent.
- S. noctiflora*** L. Night-flowering Catchfly. Fields and waste places; frequent.
- S. stellata** (L.) Ait. f. Starry Campion. Specimen in herbarium of the Jardin des Plantes, Paris, labeled "Vermont" by Michaux.

SPERGULA. Spurrey

- S. arvensis*** L. Corn Spurrey. Fields; occasional.
- S. sativa*** Boenn. Field Spurrey. Burlington, (Hazen).

SPERGULARIA. (TISSA). Sand Spurrey

- S. rubra** (L.) J. & C. Presl. Sand Spurrey. Royalton, (Ward); Brattleboro, (Grout); Mt. Holly, (Eggleston).

STELLARIA. (ALSINE). Chickweed. Starwort

- S. aquatica*** (L.) Scop. Abundant in a swamp, North Pownal, (Woodward).
- S. borealis** Bigel. Northern Stitchwort or Starwort. Cold wet places in the mountains; frequent. Burlington, (Mrs. N. F. Flynn).
- S. graminea*** L. Lesser Stitchwort or Starwort. Roadsides and moist grass lands; frequent. *Var. latifolia** Peterm. Damp grassy place, Williston, (Mrs. N. F. Flynn).
- S. longifolia** Muhl. Long-leaved Stitchwort or Starwort. Damp intervals and thickets; occasional.
- S. media*** (L.) Cyrill. Common Chickweed. In lawns and waste places; abundant.
- S. uliginosa** Murr. About cold springs, Rochester, Chittenden, (Eggleston); Vernon, (Grout); Rutland, (Kirk); Wallingford, (Kent); Brandon, (Dutton).

PORTULACACEAE. PURSLANE FAMILY

CLAYTONIA. Spring Beauty

- C. caroliniana** Michx. Spring Beauty. Rich, open woods; common.
- C. virginica** L. Spring Beauty. Intervale in Colchester, (Torrey, Jones); New Haven, (Pringle).

PORTULACA. Purslane

- P. oleracea*** L. Common Purslane. Garden weed; common.

CERATOPHYLLACEAE. HORNWORT FAMILY**CERATOPHYLLUM.** Hornwort

C. demersum L. Slow streams and ponds; frequent.

NYMPHAEACEAE. WATER LILY FAMILY**BRASENIA.** Water Shield

B. Schreberi Gmel. (*B. peltata* Pursh). Ponds; occasional.

CASTALIA. Water Lily

C. odorata (Ait.) Woodville & Wood. Sweet-scented Water Lily. Ponds and slow streams; common.

C. tuberosa (Paine) Greene. White Pond Lily. Lake Champlain and tributaries; frequent.

NYMPHAEA. Yellow Pond Lily. Spatter Dock

N. advena Ait. Cow Lily, Yellow Pond Lily, Spatter Dock. Common in ponds and slow streams. Var. *variegata* (Engelm.) Fernald. With type.

N. microphylla Pers. Small Yellow Pond Lily. Ponds and streams; frequent.

N. rubrodisca (Morong) Greene. Probably a hybrid between the two preceding species. Ponds and slow streams; occasional.

RANUNCULACEAE. CROWFOOT FAMILY**ACTAEA.** Baneberry. Cohosh

A. alba (L.) Mill. White Baneberry. Rich woods; common.

A. rubra (Ait.) Willd. Red Baneberry. Rich woods; common. Forma *neglecta* (Gill.) Robinson. Rare.

A. alba x *rubra*. Occasional.

ANEMONE. Anemone

A. canadensis L. (*A. pennsylvanica* L.). Round-headed Anemone. Stony banks; common along Lake Champlain and its tributaries.

A. cylindrica Gray. Long-fruited Anemone. Dry woods and fields of the lower altitudes; frequent.

A. multifida Poir. (*A. hudsoniana* Richards.). Cut-leaved Anemone. Colchester and Winooski Falls, (Robbins); Highgate Springs, (Jesup).

A. quinquefolia L. (*A. nemorosa* L., var. *quinquefolia* Gray). Wind Flower, Wood Anemone. Woodlands of the lower altitudes; common.

A. riparia Fernald. Gravelly and rocky banks; frequent in western and northern Vermont.

A. virginiana L. Tall Anemone. Woods and meadows of the lower altitudes; common.

ANEMONELLA. (SYNDESMON)

- A. thalictroides** (L.) Spach. Rue Anemone. North Pownal, common on rich wooded hills, (Eggleston).

AQUILEGIA. Columbine

- A. canadensis** L. Wild Columbine. Rocky places; common.
A. vulgaris* L. Garden Columbine. Common in gardens, occasional as a wayside escape, and locally abundant in Franklin County.

CALTHA. Marsh Marigold

- C. palustris** L. Cowslips. Wet meadows and swamps; common.

CLEMATIS. Virgin's Bower

- C. verticillaris** DC. (*Atragene americana* Sims.). Purple Clematis. Rocky woods of the lower altitudes; occasional.
C. virginiana L. Wild Clematis, Virgin's Bower, Traveler's Joy. River banks and moist thickets; common.

COPTIS. Goldthread

- C. trifolia** (L.) Salisb. Wet woods; common.

DELPHINIUM. Larkspur

- D. Ajacis*** L. Rocket Larkspur. Adventive; Middlebury, (Brainerd); Westminster, (Eggleston).

HEPATICA. Hepatica. Liverleaf

- H. acutiloba** DC. Sharp-lobed Hepatica. Woods; common.
H. triloba Chaix. Round-lobed Hepatica. (*H. Hepatica* Karst.). Warm open woods of the lower altitudes; frequent.

HYDRASTIS. Orange-root. Yellow Puccoon

- H. canadensis** L. Golden Seal. Shelburne, (Horsford); Weybridge, (Eggleston).

RANUNCULUS. Buttercup. Crowfoot

- R. abortivus** L. Small-flowered Crowfoot. Shady banks; common.
R. abortivus L., var. *eucyclus* Fernald. Cool woods; North Pownal, (Eggleston); West Haven, (Kirk); Burlington, (Mrs. N. F. Flynn).
R. acris* L. Tall Crowfoot or Buttercup. Everywhere common as a weed in grass lands. Var. *Steveni** (Andrz.) Lange. Common.
R. allegheniensis Britton. Mountain Crowfoot. Smugglers' Notch, (E. F. Williams); West Haven, (Kirk).
R. aquatilis L., var. *capillaceus* DC. (*Batrachium trichophyllum* [Chaix] Bosch.). Common White Water Crowfoot. Ponds and slow streams; frequent.
R. bulbosus* L. Bulbous Crowfoot or Buttercup. Sparingly introduced in fields.
R. circinatus Sibth. Stiff Water Crowfoot. (*Batrachium* S. F. Gray). Ponds and slow streams; rare.

- R. delphinifolius** Torr. Yellow Water Crowfoot. Still water and muddy banks of the lower altitudes; occasional. Var. **terrestris** (Gray) Farwell. Occasional.
- R. fascicularis** Muhl. Early Crowfoot. "Burlington," (Torrey); "Norwich," (Blanchard); "Brattleboro," (Frost); Snake Mountain, (Brainerd).
- R. Flammula** L., var. **reptans** (L.) Mey. (*R. reptans* L.) Creeping Spearwort. Sandy shores of the lower altitudes; frequent.
- R. hispidus** Michx. Wood or Early Buttercup. Abundant on dry hills, North Pownal, (Eggleston).
- R. micranthus** Nutt. Rock Crowfoot. Coventry, (Cushman).
- R. pennsylvanicus** L. f. Bristly Crowfoot. Wet places of the lower altitudes; frequent.
- R. recurvatus** Poir. Hooked Crowfoot. Moist woods and swamps; frequent; common in Windsor County.
- R. repens** L. Creeping Crowfoot or Buttercup. In lawns; Burlington, (Jones); Rutland, (Kirk). The double-flowered form of the gardens is found as an escape by wet roadsides; Underhill, (Jones, Mrs. N. F. Flynn); well established at North Dorset, (Mrs. N. F. Flynn).
- R. sceleratus** L. Cursed Crowfoot. Wet ground; Colchester and Burlington, (Mrs. N. F. Flynn).
- R. septentrionalis** Poir. Swamp Buttercup. Wet places; common.

THALICTRUM. Meadow Rue

- T. confine** Fernald. (*T. venulosum* Trel.). Rocky shores of Lake Champlain; occasional.
- T. dioicum** L. Early Meadow Rue. Rocky woodlands of the lower altitudes; common.
- T. polygamum** Muhl. Tall Meadow Rue. Moist meadows; common.

MAGNOLIACEAE. MAGNOLIA FAMILY

LIRIODENDRON. Tulip Tree

- L. Tulipifera** L. Tulip Tree, Yellow Poplar, Whitewood. "Hoosick Valley," (Mrs. Carr); North Pownal, (Eggleston); Perch Pond, Pownal, (Churchill); Bennington, (W. H. Blanchard); Arlington, Vt. Hist. Mag. 121 (1868).

MENISPERMACEAE. MOONSEED FAMILY

MENISPERMUM. Moonseed

- M. canadense** L. Moist banks and thickets of the Champlain Valley; occasional. "Weathersfield," (Barrows); Westminster, (Blanchard).

BERBERIDACEAE. BARBERRY FAMILY**BERBERIS.** Barberry

- B. vulgaris*** L. Common Barberry. Common in cultivation and a frequent escape. Especially abundant along streams in Ira, (Eggleston).

CAULOPHYLLUM. Blue Cohosh

- C. thalictroides** (L.) Michx. Pappoose Root. Rich woods; common.

PODOPHYLLUM. May Apple. Mandrake

- P. peltatum** L. "Castleton," (Branch); Middlebury, (Brainerd); common at North Pownal, (Eggleston); also occasional as a garden escape.

LAURACEAE. LAUREL FAMILY**BENZOIN.** Fever Bush. Wild Allspice

- B. aestivale** (L.) Nees. Spice Bush, Benjamin Bush. Damp woods of the lower altitudes of western Vermont; rare. Putney and Westminster, (W. H. Blanchard).

SASSAFRAS

- S. varillifolium** (Salisb.) Ktze. (*S. officinale* Nees & Eberm.). Sassafras, Cinnamon Wood. Pownal, (Robbins, Eggleston); Hartland and Brattleboro, (Bates); Vernon, (Grout).

PAPAVERACEAE. POPPY FAMILY**ARGEMONE.** Prickly Poppy

- A. mexicana*** L. Mexican Poppy. Garden escape, Hartland, (Underwood); Bradford, (Alice E. Bacon).

CHELIDONIUM. Celandine

- C. majus*** L. Waste places; frequent.

PAPAVER. Poppy

- P. Rhoeas*** L. Field or Corn Poppy. Persistent in gardens; Burlington, (Mrs. N. F. Flynn); Townshend, (W. H. Blanchard).

SANGUINARIA. Bloodroot

- S. canadensis** L. Borders of rich woods; common.

FUMARIACEAE. FUMITORY FAMILY**ADLUMIA.** Climbing Fumitory

- A. fungosa** (Ait.) Greene. Mountain Fringe, Alleghany Vine. Rich, rocky woods of the lower altitudes; occasional.

CORYDALIS. (CAPNOIDES)

- C. aurea* Willd. Golden Corydalis. Rocky banks of western Vermont; rare. Norwich, (Jesup); probably introduced.
C. sempervirens (L.) Pers. Pale Corydalis. Rocky woodlands of the lower altitudes; frequent.

DICENTRA. (BIKUKULLA)

- D. canadensis* (Goldie) Walp. Squirrel Corn. Rich woods; frequent.
D. Cucullaria (L.) Bernh. Dutchman's Breeches. Rich wooded hillsides; frequent.

FUMARIA. Fumitory

- F. officinalis** L. Common Fumitory. Occasionally persistent in old gardens.

CRUCIFERAE. MUSTARD FAMILY

ALLIARIA. Garlic Mustard

- A. officinalis** Andrz. (*A. Alliaria* [L.] Britton). Hedge Garlic. Ludlow, (Brainerd).

ARABIS. Rock Cress

- A. brachycarpa* (T. & G.) Britton. (*A. confinis* Wats. in part). Sandy soil and rocky banks; frequent along Lake Champlain.
A. canadensis L. Sickie-pod. Shady ledges of the lower altitudes; occasional.
A. Drummondii Gray. (*A. confinis* Wats. in great part). Rocky places; occasional along Lake Champlain. Gore Mt., Island Pond, (Underwood); Townshend, (Wheeler).
A. glabra (L.) Bernh. Tower Mustard. Rocks and fields; frequent.
A. hirsuta (L.) Scop. Hairy Rock Cress. Rocky places of the lower altitudes; frequent.
A. laevigata (Muhl.) Poir. Smooth Rock Cress. Rocky places of the lower altitudes; occasional.
A. lyrata L. Low Rock Cress. Mt. Equinox, Manchester, (Mary A. Day); N. Pownal, (Eggleston); West Haven, (G. H. Ross).

BARBAREA. Winter Cress

- B. stricta* Andrz. Winter Cress. Wet places; common.
B. vulgaris R. Br. (*B. Barbarea* [L.] MacM.). Common Winter Cress, Yellow Rocket. Wet places; rare.

BERTEROA

- B. incana** (L.) DC. Hoary Alyssum. A weed in lawns and by waysides; becoming frequent.

BRASSICA. Mustard. Turnip

- B. alba** (L.) Boiss. (*Sinapis alba* L.). White Mustard. Adventive; rare.

- B. arvensis*** (L.) Ktze. (*Sinapis arvensis* L.). Charlock. Fields; common.
- B. campestris*** L. Rutabaga. Fields; frequent.
- B. juncea*** (L.) Cosson. Indian Mustard. Fields; occasional.
- B. nigra*** (L.) Koch. Black Mustard. Waste places and fields; common.
- B. Rapa*** L. (*B. campestris* L.). Turnip. Persistent in gardens.

BRAYA

- B. humilis** (C. A. Mey.) Robinson. (*Arabidopsis novae-angliae* [Rydb.] Britton). Willoughby Mountain, (C. C. Frost, H. Mann).

CAMELINA. False Flax

- C. microcarpa*** Andrz. Weed in fields; occasional.

CAPSELLA. (BURSA). Shepherd's Purse

- C. Bursa-pastoris*** (L.) Medic. Shepherd's Purse. Waste places; common.

CARDAMINE. Bitter Cress

- C. bulbosa** (Schreb.) BSP. (*C. rhomboidea* DC.). Spring Cress. Cold wet meadows; Castleton, (Robbins); Middlebury, (Brainerd); Rutland and Ira, (Eggleston); West Rutland, (Mrs. N. F. Flynn).
- C. parviflora** L. Small Bitter Cress. Dry rocky woods of lower altitudes; occasional.
- C. pennsylvanica** Muhl. Bitter Cress, Brook Cress. Cold wet woods; common.
- C. pratensis** L. Cuckoo Flower. Cold wet meadows in the valleys of the Otter Creek and Castleton River and northward along Lake Champlain; occasional.

CONRINGIA. Hare's-ear Mustard

- C. orientalis*** (L.) Dumort. Railroad yard, Burlington, (Mrs. N. F. Flynn).

DENTARIA. Pepper-root. Toothwort

- D. diphylla** Michx. Pepper-root, Crinkle-root. Rich, moist woods; common.
- D. laciniata** Muhl. Cut-leaved Pepper-root. Rich woods of the Champlain Valley; occasional.
- D. maxima** Nutt. Large Pepper-root or Toothwort. Shelburne, (Pringle); Burlington, (Perkins); Norwich, (Eggleston); Rutland, (Kirk); Colchester, (Griffin).

DRABA

- D. arabisans** Michx. Mountain cliffs and headlands of Lake Champlain; occasional. Lake Champlain, (Michaux) in Herb. Mus. d'Hist. Nat., Paris.

- D. arabisans* Michx., var. *orthocarpa* Fernald & Knowlton. Willoughby Mt., (Deane).
D. stylaris J. Gay. Willoughby Mt., (Tuckerman); Smugglers' Notch, (Pringle).

ERUCA

- E. sativa** Mill. (*E. Eruca* [L.] Britton). Garden Rocket. Stowe, (Mrs. Carrie E. Straw).

ERUCASTRUM

- E. Pollichii** Schimp & Spenn. Rhod. 13: 10. Along railroad, St. Albans, (Blake).

ERYSIMUM. (CHEIRINIA). Treacle Mustard

- E. cheiranthoides* L. Worm-seed Mustard. A weed in fields; common.

HESPERIS. Rocket

- H. matronalis** L. Dame's Violet. Garden escape. Middlebury, (Brainerd); Monkton, (Eggleston).

LEPIDIUM. Peppergrass. Pepperwort

- L. apetalum** Willd. Wild Peppergrass. (*L. densiflorum* Schrad.). Dry soil, especially along railroads; common.
*L. campestre** (L.) R. Br. Field or Bastard Cress. Brattleboro, (Bates); Vergennes and Burlington, (Jones); West Haven, (Kirk); Westminster, (W. H. Blanchard).
L. virginicum L. Wild Peppergrass. Dry soil, especially along railroads; occasional.

LOBULARIA. (KONIGA). Sweet Alyssum

- L. maritima** (L.) Desv. Occasionally spontaneous in gardens and waste places.

RADICULA. Water Cress

- R. aquatica* (Eat.) Robinson. (*Neobeckia aquatica* [Eaton] Britton). Lake Cress. Marshy borders of inlets of Lake Champlain; occasional.
*R. Armoracia** (L.) Robinson. (*Armoracia Armoracia* [L.] Britton). Horseradish. Frequently established in wet ground.
*R. Nasturium-aquaticum** (L.) Britten & Rendle. (*Sisymbrium Nasturtium* L.). True Water Cress. Cool running water; Rutland and Bennington, (Eggleston); Charlotte, (Pringle); Randolph, (Bates); Westminster, (W. H. Blanchard).
R. palustris (L.) Moench. Marsh Cress. Wet places; rare.
R. palustris (L.) Moench., var. *hispida* (Desv.) Robinson. (*Radicula hispida* [Desv.] Britton). Hairy Marsh Cress. Wet places; frequent.
*R. sylvestris** (L.) Druce. Creeping Yellow Cress. Alluvial meadows of the Connecticut River; frequent. Wet meadow, South Burlington, (Mrs. N. F. Flynn). Becoming frequent in gardens.

RAPHANUS. Radish

- R. Raphanistrum*** L. Wild Radish, Jointed Charlock. "South Hero," (Robbins); Windsor, Hartland, (Eggleston); Westminster, (W. H. Blanchard); Rutland, (Kirk); Leicester, (Dutton).

SISYMBRIUM. Hedge Mustard

- S. altissimum*** L. (Norta altissima [L.] Britton). Tumble Mustard. Rapidly being introduced in fields and along roadsides.
- S. brachycarpon** Richards. (Sophia pinnata [Walt.] Greene). Hog-back Island, Colchester, (Mrs. N. F. Flynn).
- S. officinale*** (L.) Scop. (Erysimum officinale L.). Bank Cress. Waste ground. Burlington, (Mrs. N. F. Flynn); Brandon, (Dutton); Rutland, (Kirk); Colchester and Shelburne, (Blake).
- S. officinale** (L.) Scop., var. **lelocarpum*** DC. Bank Cress. Waste ground; common.

SUBULARIA. Awlwort

- S. aquatica** L. Abundant in South Pond, Marlboro, (Grout).

THLASPI. Penny Cress

- T. arvense*** L. Field Penny Cress or Mithridate Mustard. Waste places; occasional.

CAPPARIDACEAE. CAPER FAMILY

POLANISIA

- P. graveolens** Raf. Clammy-weed. Sandy shores of Lake Champlain; common.

RESEDACEAE. MIGNONETTE FAMILY

RESEDA. Mignonette. Dyer's Rocket

- R. alba*** L. White Mignonette. Garden escape; Hartland, (Helen Crandall).

SARRACENIACEAE. PITCHER PLANT FAMILY

SARRACENIA

- S. purpurea** L. Side-saddle Flower, Pitcher Plant. Sphagnum bogs; frequent. Var. **heterophylla** (Eat.) Torr. With type.

DROSERACEAE. SUNDEW FAMILY

DROSERA. Sundew

- D. longifolia** L. (D. intermedia Hayne). Long-leaved Sundew. Bogs of the lower altitudes; rare.
- D. rotundifolia** L. Round-leaved Sundew. Bogs and wet banks; occasional.

PODOSTEMACEAE. RIVER WEED FAMILY

PODOSTEMUM. River Weed.

- P. ceratophyllum** Michx. River Weed, Thread-foot. "Brattleboro," (Frost); West River, Jamaica, (Dobbin).

CRASSULACEAE. ORPINE FAMILY

PENTHORUM. Ditch Stonecrop

- P. sedoides** L. Ditches and swamps of the lower altitudes; frequent.

SEDUM. Stonecrop. Orpine

- S. acre*** L. Mossy Stonecrop. On rocks; occasional.
S. triphyllum* (Haw.) S. F. Gray. (*S. purpureum* Tausch). Rhod. 11: 46. Garden Orpine, Live-for-ever. Fields and roadsides; common.
S. roseum (L.) Scop. (*Rhodiola rosea* L.) Mt. Horrid, Rochester, (Dutton).
S. telephioides Michx. Roadside escape, Colchester, (Mrs. N. F. Flynn).

SAXIFRAGACEAE. SAXIFRAGE FAMILY

CHRYOSPLENIUM. Golden Saxifrage

- C. americanum** Schwein. Wet shady places; common.

MITELLA. Miterwort. Bishop's Cap

- M. diphylla** L. Rich woods; common.
M. nuda L. Deep moist woods, in moss; frequent.

PARNASSIA. Grass of Parnassus

- P. caroliniana** Michx. Wet banks and meadows; common in Bennington County; locally abundant in Hartland, (Underwood); occasional elsewhere.

RIBES. Currant. Gooseberry

- R. americanum** Mill. (*R. floridum* L'Her.). Rhod. 11: 46. Wild Black Currant. Moist rich woods; frequent.
R. cynosbati L. (*Grossularia cynosbati* [L.] Mill.). Prickly Gooseberry, Dogberry. Rocky woods; common.
R. lacustre (Pera.) Poir. Swamp Black Currant. Cold swamps and mountain woods; frequent.
R. oxycanthoides L. (*Grossularia oxycanthoides* [L.] Mill.). Smooth Gooseberry. Cold swamps; frequent.
R. prostratum L'Her. (*R. glandulosum* Grau.). Skunk Currant. Cold banks and mountain woods; frequent.
R. triste Pall. Swamp Red Currant. Cold swamps, mostly in the mountains. Var. *albinervium* (Michx.) Fernald. Swamps; more common than type.

R. vulgare* Lam. Garden Red Currant. Occasionally persists as an escape.

SAXIFRAGA. Saxifrage

S. aizoides L. (*Leptasea aizoides* [L.] Haw.). Yellow Mountain Saxifrage. Moist cliffs, Willoughby Mountain, (A. Wood); Smugglers' Notch, (Pringle).

S. Alzoon Jacq. (*Chondrola Alzoon* [Jacq.] Haw.). Willoughby Mountain, Smugglers' Notch, Hazen's Notch, Montgomery, (Pringle); Mt. Horrid, Rochester, (Dutton).

S. oppositifolia L. (*Antiphylla oppositifolia* [L.] Fourn.). Mountain Saxifrage. Willoughby Mountain, (A. Wood); Smugglers' Notch, (Pringle).

S. pennsylvanica L. (*Micranthes pennsylvanica* [L.] Haw.). Swamp Saxifrage. Bogs; common.

S. virginiana Michx. (*Micranthes virginiana* [Michx.] Small). Early Saxifrage. Exposed rocks and dry hillsides; common.

TIARELLA. False Miterwort

T. cordifolia L. Rich moist woods; common.

HAMAMELIDACEAE. WITCH-HAZEL FAMILY

HAMAMELIS. Witch-hazel

H. virginiana L. Low woods; common.

PLATANACEAE. PLANE TREE FAMILY

PLATANUS. Sycamore. Buttonwood

P. occidentalis L. Alluvial banks of the lower altitudes of western Vermont and north in the Connecticut Valley to Hartford; occasional.

ROSACEAE. ROSE FAMILY

AGRIMONIA. Agrimony

A. gryposepala Wallr. (*A. hirsuta* Bicknell; *A. Eupatoria* Gray's Manual, ed. 6 in part not L.). Stickseed, Cocklebur. Woods and thickets; frequent.

A. striata Michx. (*A. Brittoniana* Bicknell; *A. Eupatoria* Gray's Manual, ed. 6 in part not L.). Stickseed, Beggar-ticks. Thickets and roadsides especially in mountain towns; occasional.

AMELANCHIER. Shadbush. Juneberry. Service Berry

A. Bartramiana (Tausch.) Roemer. (*A. oligocarpa* [Michx.] Roem. Gray's Manual, ed. 7). Summits of high mountains and cold swamps; occasional.

A. canadensis (L.) Medicus. (*A. canadensis*, var. *Botryapium* [L. f.] T. & G.). Southern slopes of the lower altitudes; frequent.

- A. humilis* Wiegand. Rhod. 14: 141. (*A. spicata* Am. auth. in part). Limestone headlands and cliffs in the Champlain Valley; occasional.
- A. laevis* Wiegand. Rhod. 14: 154. (*A. canadensis* [L.] Medic.). Woods; common.
- A. sanguinea* (Pursh.) DC. (*A. rotundifolia* Roem.; *A. spicata* [Lam.] C. Koch). Rocky shores of the upper Connecticut and Champlain Valleys; occasional.
- A. stolonifera* Wiegand. Rhod. 14: 144. Rocky woods; frequent.

CRATAEGUS. Hawthorn. Thorn-apple

- C. albicans* Ashe. (*C. polita* Sarg. Rhod. 5: 11). Occasional in the lower altitudes.
- C. alnerum* Sarg. Rhod. 5: 153. (*C. Edsoni* Sarg. Rhod. 7: 205; *C. contigua* Sarg. Rhod. 5: 115). Burlington, (A. W. Edson); Stockbridge, (Eggleston); Bellows Falls and Westminster, (W. H. Blanchard).
- C. anomala* Sarg. Rhod. 3: 74. Clarendon, (Eggleston); Bridport, (Brainerd).
- C. Boytoni* Beadle. (*C. foetida* Ashe). Vernon, (W. H. Blanchard).
- C. Brainerdi* Sarg. Rhod. 3: 27. Lower altitudes; occasional. Var. *scabrida* (Sarg.) Eggl. (*C. scabrida* Sarg. Rhod. 3: 29). Middlebury, (Brainerd); West Rutland and Bennington, (Eggleston).
- C. Brainerdi* Sarg., var. *Egglestoni* (Sarg.) Robinson. (*C. Egglestoni* Sarg. Rhod. 3: 30). Common; particularly in the hill towns; reaching an altitude of 2,300 feet. Var. *asperifolia* (Sarg.) Eggl. (*C. asperifolia* Sarg. Rhod. 3: 31). Middlebury, (Brainerd).
- C. champlainensis* Sarg. Rhod. 3: 20. Champlain Valley; frequent. Birdseye Mt., Ira, (Kirk).
- C. chrysocarpa* Ashe. (*C. rotundifolia* Borkh.; *C. coccinea rotundifolia* Sarg. Bot. Gaz. 31: 14; *C. Gravesii* Sarg. Rhod. 5: 159). Champlain and Connecticut Valleys; occasional.
- C. chrysocarpa* Ashe, var. *Faxoni* (Sarg.) Eggl. (*C. Faxoni* Sarg. Rhod. 5: 161). With type.
- C. coccinioides* Ashe, var. *dilatata* (Sarg.) Eggl. (*C. dilatata* Sarg. Bot. Gaz. 31: 9). Addison County; common. (Brainerd).
- C. Crus-galli** L. Cockspur Thorn. Ferrisburg, (Horsford); Mt. Independence, (Eggleston); Gardiner's Island, Ferrisburg, (C. E. Pinney); Chimney Point, (Brainerd); West Haven, (Kirk and Ross). This species is unquestionably introduced in the State.
- C. filipes* Ashe. (*C. silvicola* Beadle, var. *Beckwithae* [Sarg.] Eggl.; *C. Robbinsiana* Sarg. Rhod. 7: 197). Putney and Westminster, (W. H. Blanchard); Burlington, (Eggleston).
- C. Grayana* Eggleston. Rhod. 10: 80. (*C. fiabellata* Sarg. Rhod. 3: 75). Bellows Falls and Westminster, (W. H. Blanchard).
- C. intricata* J. Lange. (*C. coccinea* Eggleston in Gray's Manual; *C. modesta* Sarg. Rhod. 3: 28). West Rutland, Arlington, (Eggleston); Carver's Falls, West Haven, (Eggleston, Kirk and Ross).

- C. Irrasa* Sarg., var. *Blanchardi* (Sarg.) Eggl. (*C. Blanchardi* Sarg. Rhod. 7: 208). Wilmington and Whitingham, (Eggleston).
- C. Jesupi* Sarg. Rhod. 5: 61. Twin Mts., West Rutland, (Eggleston).
- C. Kennedyi* Sarg. Tree and Shrubs 2: 73, 134. (*C. media* Eggl. Rhod. 6: 141). Summit of Willoughby Mt., about 2,600 ft. alt., (E. Faxon, Eggleston, Kennedy). Rare and local.
- C. lucorum* Sarg., var. *insolens* (Sarg.) Eggl. Rhod. 10: 79. (*C. insolens* Sarg. Rhod. 7: 217). West Concord, (Eggleston).
- C. macrosperma* Ashe. (*C. delucida* Sarg. Rhod. 5: 139). Common in the lower altitudes. Var. *demissa* (Sarg.) Eggl. (*C. demissa* Sarg. Rhod. 5: 139). Burlington, (Eggleston). Var. *pentandra* (Sarg.) Eggl. Rhod. 10: 80. (*C. pentandra* Sarg. Rhod. 3: 25). With the type; occasional.
- C. macrosperma* Ashe, var. *pastorum* (Sarg.) Eggl. Rhod. 10: 80. (*C. pastorum* Sarg. Rhod. 3: 24; *C. genialis* Sarg. Rhod. 5, 148). Moist lowland and pastures; occasional. Var. *matura* (Sarg.) Eggl. (*C. matura* Sarg. Rhod. 3: 24). With the type.
- C. monogyna** Jacq. (*C. Oxyacantha* of the Manuals). English Hawthorn. Occasionally escaped from cultivation. Peacham, (Blanchard); Burlington, (Jones); Knight's Island, (Brainerd).
- C. neofluvialis* Ashe. (*C. macracantha* Lodd., var. *neofluvialis* [Ashe] Eggl. Rhod. 10: 83). Cornwall, (Brainerd).
- C. Oakesiana* Eggleston. *Torreya* 7: 35. Bloomfield, Lemington, (Eggleston); Canaan, (Frizzell). Common along the Connecticut River.
- C. Pringlei* Sarg. Rhod. 3: 21. Charlotte, (Pringle); Middlebury, (Brainerd); Rutland, (Eggleston); Westminster, (W. H. Blanchard). Var. *exclusa* (Sarg.) Eggl. (*C. exclusa* Sarg. Rhod. 5: 108). With the type; occasional. Var. *lobulata* (Sarg.) Eggl. (*C. lobulata* Sarg. Rhod. 3: 22). Addison County, (Brainerd).
- C. pruinosa* (Wendl.) K. Koch. Occasional in the lower altitudes. Forma *dissona* (Sarg.) Eggl. Rhod. 10: 81. (*C. dissona* Sarg. Rhod. 5: 60). Putney, (W. H. Blanchard). Var. *philadelphica* (Sarg.) Eggl. (*C. philadelphica* Sarg. Proc. Acad. Sci., Philadelphia, 588 [1905]). Burlington, (Eggleston).
- C. punctata* Jacq. Dotted Thorn. Common and widely distributed throughout the lower levels and reaching at least 1,500 feet in altitude. Var. *canescens* Britton. With the type; rare. Var. *rubra* Ait. With the type; common.
- C. roanensis* Ashe. (*C. ascendens* Sarg. Rhod. 5: 141). In the lower altitudes; occasional.
- C. straminea* Beadle. (*C. intricata* Sarg. Rhod. 3: 28). West Rutland, (Eggleston); Burlington, (A. W. Edson); Arlington, (W. H. Blanchard).
- C. submollis* Sarg. Bot. Gaz. 31: 1. Weybridge, (Brainerd).
- C. succulenta* Schrad. (*C. macracantha* Lodd.). Long-spine Thorn. Moist thickets and rich hillsides of the lower altitudes; common.

- C. succulenta* Schrad., var. *major* n. n. Eggleston. (*C. macracantha* Lodd., var. *succulenta* Eggleston. Rhod. 10: 82). With the type, in the Champlain Valley; rare.
- C. succulenta* Schrad., var. *rhombifolia* (Sarg.) n. n. Eggleston. (*C. rhombifolia* Sarg. Rhod. 5: 183). With type; frequent.
- C. villipes* Ashe. (*C. Holmesiana* Ashe). Common in the lower altitudes.

DALIBARDA

- D. repens* L. Dalibarda. Cool moist woods; frequent.

FILIPENDULA

- F. rubra* (Hill) Robinson. (*Ulmaria rubra* Hill). Queen of the Prairie. Roadside escape; occasional.
- F. Ulmaria** (L.) Maxim. (*Ulmaria Ulmaria* Borkh.). Queen of the Meadow. Roadside escape; rare.
- F. vulgaris** Moench. Dropwort. A well established roadside escape, Burlington, (Mrs. N. F. Flynn).

FRAGARIA. Strawberry

- F. vesca** L. Dooryard, Middlebury, (Brainerd).
- F. vesca* L., var. *americana* Porter. (*F. americana* Britton). Wild or American Wood Strawberry. Woods; common.
- F. virginiana* Duchesne. Wild or Field Strawberry. Fields; common.

GEUM. Avens

- G. canadense* Jacq. (*G. album* Gmelin). White Avens. Borders of woods of the lower altitudes; common.
- G. macrophyllum* Willd. Moist open mountain woods; common above 1,500 feet altitude. Unknown on Willoughby Mt.
- X *G. pulchrum* Fernald. (*G. macrophyllum* x *rivale*). Mendon, (Eggleston).
- G. rivale* L. Water or Purple Avens. Wet meadows and bogs; common.
- G. strictum* Ait. Yellow Avens. Moist meadows; common.
- C. virginianum* L. Rough Avens. Middlebury, (Brainerd); Burlington, (Mrs. N. F. Flynn); Rutland, (Kirk); Bennington, (Dutton).

PHYSOCARPUS. (OPULASTER). Nine-bark

- P. opulifolius* (L.) Maxim. Well established in the vicinity of "Retreat Park," E. Rattleboro, (Wheeler).

POTENTILLA. Cinquefoil. Five-finger

- P. Anserina* L. (Argentina *Anserina* [L.] Rydb.). Silver Weed. Common on the beaches of Lake Champlain and established where introduced in ballast along railroads.
- P. Anserina* L., var. *sericea* Hayne. Rhod. 11: 48. Burlington, (Mrs. N. F. Flynn); Sphagnum bog, foot of Mt. Killington, (Kirk).
- P. argentea* L. Silvery Cinquefoil. Dry barren fields; common.

- P. arguta* Pursh. (Dry mocallis agri monioides [Pursh] Rydb.). Tall Cinquefoil. Rocky hills of the lower altitudes; occasional.
- P. canadensis* L. Cinquefoil, Five-finger. Rocky hills and waste places of the lower altitudes.
- P. canadensis* L., var. *simplex* (Michx.) T. & G. (*P. simplex* Michx.). Cinquefoil, Five-finger. Waste places and dry sand; much more common than type on the eastern side of the state.
- P. fruticosa* L. (*Dasiphora fruticosa* [L.] Rydb.). Shrubby Cinquefoil. Swamps and moist cliffs. Smugglers' Notch; Lake Willoughby. Troublesome as a pasture weed in southwestern Vermont. Becoming locally established in Hartland, (Underwood).
- P. monspeliensis* L. Rough Cinquefoil. Dry soil; frequent.
- P. monspeliensis* L., var. *labradorica* (Lehm.) Fernald. Smugglers' Notch.
- P. monspeliensis* L., var. *norvegica* (L.) Rydb. Along railroad, Essex; pasture, Fairfield, (Blake).
- P. palustris* (L.) Scop. (*Comarum palustre* L.). Marsh Cinquefoil. Cool bogs; frequent. *Forma subsericea* occurs.
- P. recta** L. Brattleboro, (Bates); Rutland, (Eggleston); Brandon, (Dutton); Burlington, (Hazen); Colchester, (Mrs. N. F. Flynn).
- P. tridentata* Ait. (*Sibbaldiopsis tridentata* [Soland.] Rydb.). Three-toothed or Mountain Cinquefoil. Summits of cliffs and mountains; occasional, e. g. Mt. Mansfield, Camel's Hump, Snake Mountain, Pownal, Mt. Horrid.

PRUNUS. Plum. Cherry

- P. avium** L. Sweet Cherry, Mazzard Cherry. Manchester, (Mary A. Day).
- P. cuneata* Raf. Appalachian Cherry. Sand banks of lake shore, Burlington, (Pringle). Frequent on the sand plains in the vicinity of Burlington.
- P. nigra* Ait. Wild or Canada Plum. Woods and fence rows; frequent. Never native in eastern Vermont; (W. H. Blanchard).
- P. pennsylvanica* L. f. Wild Red, Bird or Pin Cherry. Roadside thickets; common.
- P. pumila* L. Sand Cherry. Rocky or sandy shores of the Connecticut and Champlain Valleys; occasional.
- P. serotina* Ehrh. (*Padus virginiana* [L.] Mill.). Black Cherry. Woodlands; common.
- P. virginiana* L. (*Padus nana* [Du Roi] Roem.). Choke Cherry. Fencerows, woods and banks; common. Var. *leucocarpa* Wats. Lunenburg, (Annette Bell); Franklin, (Hazel Riley).

PYRUS

- P. americana* (Marsh.) DC. (*Sorbus americana* Marsh.). American Mountain Ash. Swamps and mountain woods; frequent.
- P. arbutifolia* (L.) L. f. (*Aronia arbutifolia* [L.] Ell.). Red Chokeberry. Swamp, Burlington, (Rand).

- P. arbutifolia* (L.) L. f., var. *atropurpurea* (Britton) Robinson. (*Aronia atropurpurea* Britton). Purple Chokeberry. Swamps; occasional.
- P. aucuparia** (L.) Ehrh. (*Sorbus aucuparia* L.). European Mountain Ash. Peacham, (Blanchard); frequent about Burlington, (Jones); pastures, Middlebury, (Brainerd).
- P. communis** L. Pear. A rare escape.
- P. Malus** L. (Malas Malus [L.] Britton). Apple. Thickets and fence rows; common.
- P. melanocarpa* (Michx.) Willd. (*Aronia melanocarpa* [Michx.] Britton). Black Chokeberry. Moist woods and rocky uplands; common.
- P. stitchensis* (Roem.) Piper. (*Sorbus scopulina* Greene). Mt. Mansfield, Willoughby Mt., (Pringle); Killington Mt., (Kirk); Stratton, (Underwood).

ROSA. Rose

- R. acicularis*, Lindl., var. *Bourgeaulana* Crepin. Prickly Rose. Snake Mountain and Burlington, (Brainerd); Manchester, (Mary A. Day); Birdseye Mt., (Kirk); Arlington, (W. H. Blanchard).
- R. blanda* Ait. Smooth Rose. Roadsides and ledges; frequent.
- R. carolina* L. Swamp Rose. Borders of swamps and streams of the lower altitudes; common.
- R. cinnamomea** L. Cinnamon Rose. Roadsides and about old gardens; frequent.
- R. gallica** L. French Rose. Garden escape; rare.
- R. humilis* Marsh. (*R. virginiana* Mill.). Pasture Rose. Dry rocky slopes of the lower altitudes; common.
- R. nitida* Willd. Shining Rose. Bradford, (Alice E. Bacon).
- R. rubiginosa** L. Sweetbrier. Old pastures; common.
- R. spinosissima** L. Scotch Rose. Occasionally spreading from gardens.
- R. virginiana* Mill. Large Wild Rose. (*R. lucida* Ehrh.). North Pownal, (Eggleston); West Haven, (Ross and Kirk).

RUBUS. Raspberry. Blackberry. Bramble

- X *R. abbrevians* Blanchard. (*R. pergratus* x *setosus*). Occasional in uplands of Windham County.
- R. allegheniensis* Porter. (*R. nigrobaccus* Bailey). High-bush Blackberry. Dry thickets and recent clearings; common. *Forma albinus* (Bailey) Fernald. Pittsfield, (Mrs. Mary E. Eggleston).
- R. arenicola* Blanchard. (?A form derived from *R. procumbens* x *recurvans*); Starr Farm, Burlington.
- R. argutus* Link. (*R. Andrewsianus* Blanchard; *R. floricomus* Blanchard). Champlain and Connecticut Valleys; rare.
- R. Brainerdi* Rydb. (*R. sativus* Gray's Man., ed. 7). Alluvial soil, Weybridge.
- R. canadensis* L. Common in the mountains.

- X *R. cubitans* Blanchard. (*R. hispidus* x *procumbens*). Westminster, Stratton.
- R. elegantulus* Blanchard. Frequent in Windham County.
- X *R. flavinanus* Blanchard. (*R. allegheniensis* x *elegantulus*). Found only in Stratton.
- X *R. frondisentis* Blanchard. (*R. allegheniensis* x *setosus*). Townshend, Stratton, Berkshire.
- X *R. Groutianus* Blanchard. (*R. elegantulus* x *setosus*). Wardsboro, Stratton.
- R. heterophyllus* Willd. (Apparently derived from *R. procumbens* x *recurvans*). Frequent along the Otter Creek in Middlebury and Weybridge; also at Starr Farm, Burlington.
- R. hispidus* L. Running Swamp Blackberry. Low woods and moist open fields; common.
- R. idaeus* L., var. *aculeatissimus* (C. A. Mey.) Regel & Tiling. (*R. strigosus* Michx.). Red Raspberry. Thickets and hills; common.
- R. idaeus* L., var. *anomalus* Arrhenius. (*R. Egglestonii* Blanchard). Cavendish, (Eggleston); Townshend, (Wheeler).
- X *R. jacens* Blanchard. (*R. procumbens* x *setosus*). Stratton, Wardsboro.
- X *R. neglectus* Peck. (*R. idaeus*, var. *aculeatissimus* x *occidentalis*). Purple Raspberry. Ledgy fields and recent clearings; occasional.
- R. occidentalis* L. Black Raspberry, Thimbleberry. Fence rows and rich shady slopes; common.
- R. odoratus* L. Purple Flowering Raspberry. Moist shady hillsides; frequent.
- R. pergratus* Blanchard. Thickets and woodland borders; frequent.
- X *R. permixtus* Blanchard. (*R. allegheniensis* x *hispidus*). Fence rows and borders of thickets; Westminster, Putney, Burlington.
- X *R. plicatifolius* Blanchard. (*R. procumbens* x *recurvans*; ? *R. villosus* Ait.). Middlebury, Burlington, Essex.
- R. procumbens* Muhl. Dewberry, Running or Low Blackberry. Occasional both in typical and in several variant forms, e. g.: *R. geophilus* Blanchard and *R. Baileyanus* Britton.
- R. pubescens* Raf. (*R. triflorus* Richards.) Rhod. 11: 236. Dwarf or Running Raspberry. Moist cool soil; common.
- R. recurvans* Blanchard. Thickets and open fields; common.
- R. setosus* Bigelow. (*R. nigricans* Rydb.). Frequent at high altitudes; also at alt. 150 ft., Burlington.
- X *R. trifrons* Blanchard. (*R. hispidus* x *setosus*). Marlboro, Stratton, Wardsboro, Ripton, Burlington; locally abundant.
- R. vermontanus* Blanchard. (*R. nigricans* Gray's Man., ed. 7). Frequent above 1,000 ft. altitude.
- X *R. vermontanus*, var. *viridifolius* Blanchard. (*R. setosus* x *vermontanus*). Leicester, Rutland, Windham, Stratton, Wardsboro.
- Also the following intermediate forms, evidently the result of crossing, have been observed among the high-bush species:
- R. allegheniensis* x *canadensis*. Ripton, Stratton.

- R. allegheniensis* x *pergratus*. Wardsboro, Stratton.
R. allegheniensis x *recurvans*. Burlington.
R. canadensis x *pergratus*. Stratton, Wardsboro.
R. hispidus x *recurvans*. Fair Haven and West Haven; frequent.

SANGUISORBA. Burnet

- S. canadensis* L. Canadian Burnet. Brattleboro, (Frost); banks of the West, River, (Grout).
S. minor Scop. (*Poterium Sanguisorba* L.). Garden Burnet. Charlotte Center, (Pringle); Shelburne, (Mrs. N. F. Flynn).

SORBARIA. (SCHIZONOTUS)

- S. sorbifolia** (L.) A. Br. (*Spiraea sorbifolia* L.). Ash-leaved Spiraea. Garden escape; frequent.

SPIRAEA

- S. latifolia* (Ait.) Borkh. Meadow-sweet. Pastures; common.
S. salicifolia L. (*Spiraea alba* Du Roi). Meadow-sweet. Swanton, (Blake); Alburg, (C. H. Knowlton).
S. tomentosa L. Steeple Bush, Hard Hack. Rocky pastures; common.

WALDSTEINIA

- W. fragarioides* (Michx.) Trattinick. Barren Strawberry. Wooded hillsides and old pastures of the lower altitudes; common.

LEGUMINOSAE. PULSE FAMILY

AMORPHA. False Indigo

- A. fruticosa* L. Established at Retreat Park, Brattleboro, (Wheeler).

AMPHICARPA. Hog Peanut

- A. monoica* (L.) Ell. (*Falcata comosa* [L.] Ktze.). Thickets; common.
A. Pitcheri T. & G. Along the river, Norwich, (E. F. Williams).

APIOS. Ground-nut. Wild Bean

- A. tuberosa* Moench. (*Glycine Aplos* L.) Low moist ground; frequent.

ASTRAGALUS

- A. alpinus* L., var. *Brunellianus* Fernald. Rocky shores of Connecticut River; occasional.
A. Blakei Eggleston. Cliffs; Smugglers' Notch and Underhill Notch, Mt. Mansfield, type stations. Willoughby Mountain, (J. Blake); Mt. Hanley, West Rutland, (Kirk); rocky shores of Connecticut River, (Eggleston).
A. canadensis L. (*A. carolinianus* L.) Shores and islands of Lake Champlain; frequent.
A. Robbinsii (Oakes) Gray. On limestone rocks, near High Bridge, Winoski River, Burlington, (Robbins). This, the only station in Vermont, was destroyed in 1894 by the set back of the dam of the Vermont Electrical Power Company.

BAPTISIA. False Indigo

B. australis (L.) R. Br. Blue False Indigo. Royalton, (Ward).

B. tinctoria (L.) R. Br. Wild Indigo. Dry open fields; Vernon, (Grout); Pownal, (Churchill).

CASSIA. Senna

C. marilandica L. Wild Senna. Alluvial soil; "Orwell," (Dr. Hill); Bellows Falls, (Carey, W. H. Blanchard); Randolph, (Bates); Hartford, (Jesup); Brandon, (Dutton).

C. nictitans L. (*Chamaecrista nictitans* [L.] Moench). Wild Sensitive plant. Vernon, (Grout).

CICER

C. arietinum* L. Chick-pea. Railway embankment, Colchester, (Mrs. N. F. Flynn).

CORONILLA

C. varia* L. Crown Vetch. Garden escape; Randolph, (Bates).

CROTALARIA. Rattle-box

C. sagittalis L. Railroad banks; Vernon, (Grout).

DESMODIUM. (MEIBOMIA). Tick Trefoil

D. bracteosum (Michx.) DC. Dry thickets; West Rutland, (A. W. Driggs, Eggleston); North Pownal and Arlington, (Eggleston); South Pownal, (W. H. Blanchard).

D. canadense (L.) DC. Showy Tick Trefoil. Dry rich woods of the lower altitudes; common.

D. Dillenii Darl. Open woodlands of the lower altitudes; frequent.

D. grandiflorum (Walt.) DC. (*D. acuminatum* DC.). Rich woods of the lower altitudes; common.

D. nudiflorum (L.) DC. Dry woods of the lower altitudes; common.

D. paniculatum (L.) DC. Copses of the lower altitudes of western Vermont and north in the Connecticut Valley to Westminster; occasional.

D. rigidum (Ell.) DC. North Pownal, (Eggleston); Vernon, (W. H. Blanchard).

D. rotundifolium (Michx.) DC. (*Meibomia Michauxii* Vail). Dummerston, (Wild); Bellows Falls, (Blanchard); North Pownal, (Bates).

HEDYSARUM

H. boreale Nutt. Willoughby Mountain, (A. Wood); Smugglers' Notch, (Pringle).

LATHYRUS. Everlasting Pea. Vetchling

L. latifolius* L. Everlasting or Perennial Pea. Along railroad, Newfane, (Jones).

L. maritimus (L.) Bigel. Beach Pea. Shores of Lake Champlain; occasional.

- L. ochroleucus* Hook. Headlands of northern Lake Champlain; occasional.
- L. palustris* L. Marsh Pea. Shores of Lake Champlain; frequent.
- L. palustris* L., var. *myrtifolius* (Muhl.) Gray. (*L. myrtifolius* Muhl.). "Vermont," (Torrey and Gray); "Island in Ferrisburgh," (Morong), in Walter Deane herbarium, Cambridge, Mass.
- L. tuberosus** L. Vergennes, (Miss Ruth Fisher).

LESPEDEZA. Bush Clover

- L. capitata* Michx. Sandy soil of the lower altitudes; frequent.
- L. frutescens* (L.) Britton. Dry open places in the lower altitudes of southern Vermont; occasional.
- L. hirta* (L.) Hornem. Dry open woods of the lower altitudes of southern Vermont; occasional.
- L. Nuttallii* Darl. Vernon, (W. H. Blanchard).
- L. Stuebeli* Nutt. Vernon, (W. H. Blanchard).
- L. violacea* (L.) Pers. Bush Clover. Dry woods. "Rockingham," (Carey); Gardiner's Island, (Pringle).

LUPINUS

- L. perennis* L. Wild Lupine. Common in sand plains along Lake Champlain.

MEDICAGO. Medick

- M. arabica** Huds. Spotted Medick. Experiment Farm, Burlington, (Jones).
- M. hispida** Gaertn. Bur Clover. Ludlow, (Miss Pollard); Hartland, (Ruggles); Burlington, (Jones).
- M. lupulina** L. Black Medick, Nonesuch. Roadsides and fields; common.
- M. sativa** L. Alfalfa, Lucerne. Often cultivated and persistent; occasional as an escape.

MELILOTUS. Sweet Clover

- M. alba** Desr. White Melilot, White Sweet Clover. Waste or cultivated grounds; frequent.
- M. officinalis** (L.) Lam. Yellow Melilot, Yellow Sweet Clover. Roadsides or waste places; occasional.

ONOBRYCHIS. Sainfoin

- O. sativa** Lam. Experiment Farm, Burlington, (Jones).

ROBINIA. Locust

- R. hispida* L. Bristly Locust, Rose Acacia. Occasional as an escape. Well established, Jamaica, (Wheeler).
- R. Pseudo-Acacia* L. Common Locust, False Acacia. Frequent in cultivation and as an escape.

- R. viscosa** Vent. Clammy Locust. Occasional in cultivation and tending to spread.

TRIFOLIUM. Clover

- T. agrarium*** L. Yellow or Hop Clover. Sandy soil; frequent.
T. arvense* L. Rabbit-foot Clover. Old fields; frequent.
T. hybridum* L. Alsike Clover. Common.
T. incarnatum* L. Crimson or Italian Clover. Willoughby Lake, (Kennedy).
T. pratense* L. Red Clover. Common.
T. procumbens* L. Low Hop Clover. Burlington, (Mrs. N. F. Flynn); St. Albans, (Blewitt); along railroad, Rutland, (Kirk).
T. repens L. White Clover. Common.

VICIA. Vetch. Tare

- V. angustifolia*** Reichenbach. Common Vetch. Middlebury, (Brainerd); Hartland, (Underwood). Var. **segetalis*** (Thuill.) Koch. Roadsides and along railroads; occasional.
V. Cracca L. Blue Vetch. Meadows and roadsides; frequent.
V. sativa* L. Spring Vetch. Occasional. White flowered form, Starr Farm, Burlington, (Mrs. N. F. Flynn).
V. tetrasperma* (L.) Moench. Slender Vetch. Meadows and pastures; occasional.
V. villosa* Roth. Hairy or Winter Vetch. Persisting in cultivated ground.

LINACEAE. FLAX FAMILY

LINUM. Flax

- L. medium** (Planch.) Britton. (*Cathartolimum medium* [Planch.] Small). Arlington, (W. H. Blanchard).
L. sulcatum Riddell. (*Cathartolimum sulcatum* [Riddell] Small). Rutland, (Dutton); Pownal, (W. H. Blanchard).
L. usitatissimum* L. Common Flax. Occasionally adventive, especially along railroads.

OXALIDACEAE. WOOD SORREL FAMILY

OXALIS. Wood Sorrel

- O. Acetosella** L. Common Wood Sorrel. Cool moist woods; common on mountain sides. Var. **subpurpurascens** DC. Stratton, (Wheeler); Manchester, (Grout).
O. corniculata L. (*Xanthoxalis corniculata* [L.] Small). Lady's Sorrel. Fields and gardens; common.
O. filipes Small. (*Xanthoxalis filipes* Small). Slender Yellow Wood Sorrel. Pownal, (Hazen).
O. repens Thunb. A weed in greenhouses; frequent.
O. stricta L. (*Xanthoxalis stricta* [L.] Small). Yellow Wood Sorrel. Burlington, (Hazen); Rutland, (Dutton).

GERANIACEAE. GERANIUM FAMILY

ERODIUM. Storksbill

- E. Botrys** Bertol. On wool waste, Burlington, (Brainerd).
*E. cicutarium** (L.) L'Her. Storksbill. Old gardens. Ludlow, (Miss Pollard); Burlington, (Mrs. A. J. Grout).
*E. moschatum** (L.) L'Her. Musk Storksbill. On wool waste, Burlington, (Brainerd).

GERANIUM. Cranesbill

- G. Bicknellii* Britton. Dry rocky places; frequent in western Vermont and in the Connecticut Valley north to Norwich, (Eggleston).
G. maculatum L. Cranesbill. Open woods; frequent at low altitudes in western Vermont and in the Connecticut Valley north to Norwich, (Jesup); St. Johnsbury, (Inez A. Howe).
G. Robertianum L. (*Robertiella Robertiana* [L.] Hanks). Herb Robert. Rocky woods and ravines; common.

RUTACEAE. RUE FAMILY

RUTA. Rue

- R. graveolens** L. Well established at Weybridge, (Brainerd).

ZANTHOXYLUM. Prickly Ash

- Z. americanum* Mill. Rocky woods and banks; occasional at low altitudes in western Vermont. "Norwich, Hartford," (Jesup); Sharon, (Jesup and Sargent); Peacham, (Blanchard). Perhaps introduced in eastern Vermont.

POLYGALACEAE. MILKWORT FAMILY

POLYGALA. Milkwort

- P. paucifolia* Willd. Fringed Polygala, Flowering Wintergreen. Common, especially in light soil at low altitudes.
P. polygama Walt. Milkwort. Dry sandy soil of western Vermont; occasional. North in the Connecticut Valley to Bellows Falls.
P. sanguinea L. (*P. viridescens* L.). Purple Milkwort. Moist sandy soil; Windsor, (Leland); Newfane, (Grout); Burlington, (Mrs. N. F. Flynn); Milton, (Jones); Rutland, (Kirk).
P. Senega L. Seneca Snake-root. Rocky soil, western Vermont; occasional.
P. verticillata L. Whorled Milkwort. Sandy soil; "Bellows Falls," (Tuckerman); Brattleboro, (Grout); Vernon, (B. L. Robinson); Pownal, (Eggleston); Townshend, (Wheeler).
P. verticillata L., var. *ambigua* (Nutt.) Wood. (*P. ambigua* Nutt.). Pownal, (Robbins); Vernon, (B. L. Robinson); Brattleboro, (Grout); Burlington, (Howe). Vernon to Bellows Falls, (W. H. Blanchard).

EUPHORBIACEAE. SPURGE FAMILY

ACALYPHA. Three-seeded Mercury

A. virginica L. Moist hollows in fields; frequent.

EUPHORBIA. Spurge

E. corollata L. (*Tithymalopsis corollata* [L.] Kl. & Garcke). Flowering Spurge. Sandy field, Burlington, (Mrs. N. F. Flynn); recently introduced from the west.**E. Cyparissias*** L. (*Tithymalus Cyparissias* [L.] Hill). Cypress Spurge. Old cemeteries and roadsides; common.**E. hirsuta** (Torr.) Wiegand. (*Chamaesyce Rafinesqui* [Greene] Small). Along railroad, Swanton, (Blake).**E. Helioscopia*** L. (*Tithymalus Helioscopia* [L.] Hill). Wartweed. Waste places and gravelly shores; frequent in the Champlain Valley.**E. hirsuta** (Torr.) Wiegand. (*Chamaesyce Rafinesqui* [Greene] Small). Sandy soil; common.**E. maculata** L. (*Chamaesyce maculata* [L.] Small). Milk Purslane. Common in waste places.**E. Peplus*** L. (*Tithymalus Peplus* [L.] Hill). Petty Spurge. Charlotte, (Pringle); Wallingford, (Brainerd); Westminster, (Blanchard).**E. platyphylla*** L. (*Tithymalus platyphyllus* [L.] Hill). Shores and waste places; occasional.**E. Preslii** Guss. (*Chamaesyce Preslii* [Guss.] Arthur). Waste places; occasional.**CALLITRICHACEAE. WATER STARWORT FAMILY**

CALLITRICHE. Water Starwort

C. autumnalis L. Kelly's Bay, Alburgh, (Pringle).**C. palustris** L. Cold or running water; frequent.**EMPETRACEAE. CROWBERRY FAMILY**

EMPETRUM. Crowberry

E. nigrum L. Black Crowberry. Summits of Mt. Mansfield and Camel's Hump, (Robbins).**LIMNANTHACEAE. FALSE MERMAID FAMILY**

FLOERKEA. False Mermaid

F. proserpinacoides Willd. Castleton, (Robbins); Shelburne, (Pringle).**ANACARDIACEAE. CASHEW FAMILY**

RHUS. Sumach

R. canadensis Marsh. (*Schmaltzia crenata* [Mill.] Greene). Sweet-

- scented Sumach. Dry rocky banks of western Vermont; occasional.
- R. copallina** L. Dwarf Sumach. Rocky hills of the lower altitudes; frequent. North in the Connecticut Valley to Fairlee, (Jesup).
- R. glabra** L. Smooth Sumach. Rocky soil; common in the lower Connecticut and the Hoosic Valleys. South Charlotte, (Horsford); Colchester, (Mrs. N. F. Flynn); Brandon, (Dutton); Rutland, (Kirk).
- R. Toxicodendron** L. Poison Ivy, Poison Oak. Banks and moist thickets; common. Var. *radicans* (L.) Torr. In woods; frequent.
- R. typhina** L. Staghorn Sumach. Hillsides; common. *Forma laciniata* (Wood.) Rehder. Rutland, (Eggleston); Hartland, (May Rogers).
- R. Vernix** L. (*Toxicodendron Vernix* [L.] Ktze.). Poison Sumach, Poison Dogwood. Occasional in swamps in the lower altitudes; rare in the southern Connecticut Valley.

AQUIFOLIACEAE. HOLLY FAMILY

ILEX. Holly

- I. verticillata** (L.) Gray. Black Alder, Winterberry. Thickets; common.
- I. verticillata** (L.) Gray, var. *padifolia* (Willd.) T. & G. Colchester, (Griffin).
- I. verticillata** (L.) Gray, var. *tenuifolia* (Torr.) Wats. (*I. bronxensis* Britton). Mouth of Winooski River, (Eggleston); Stratton, (Underwood); Dame Island, North Hero and Savage Island, Grand Isle, (Brainerd).

NEMOPANTHUS. (ILICIOIDES). Mountain Holly

- N. mucronata** (L.) Trel. Cold wet woods; frequent.

CELASTRACEAE. STAFF TREE FAMILY.

CELASTRUS. Staff Tree

- C. scandens** L. Waxwork, Climbing Bitter-sweet. Moist banks and thickets; common.

STAPHYLEACEAE. BLADDER NUT FAMILY

STAPHYLEA. Bladder Nut

- S. trifolia** L. American Bladder Nut. Moist woods and thickets; occasional at low altitudes in western Vermont, and north in the Connecticut Valley to Norwich, (Sargent).

ACERACEAE. MAPLE FAMILY

ACER. Maple

- A. Negundo** L. Box Elder. Abundant in some localities on the banks of the Winooski River from Montpelier to Burlington; bank of Connecticut River, Hartland, (Underwood).

- A. pennsylvanicum** L. Striped Maple, Moosewood. Rich woods; common.
- A. rubrum** L. Red or Swamp Maple. Moist woods and swamps; common.
- A. saccharinum** L. White or Silver Maple. Banks of rivers and lakes at low altitudes; frequent.
- A. saccharum** Marsh. Sugar or Rock Maple. Rich woods; common.
- A. saccharum** Marsh, var. **niigrum** (Michx. f.) Britton. Black Sugar Maple. Moist soil, Lake Champlain Valley; occasional. "Windsor," (Michaux); Arlington, (W. H. Blanchard); St. Johnsbury, (Bridget M. Rooney).
- A. spicatum** Lam. Mountain Maple. Cool ravines and mountain woodlands; common.

SAPINDACEAE. SOAPBERRY FAMILY

AESCULUS. Horse-chestnut. Buckeye

- A. Hippocastanum*** L. Common Horse-chestnut. Commonly planted and occasionally spontaneous.

BALSAMINACEAE. TOUCH-ME-NOT FAMILY

IMPATIENS. Balsam. Jewelweed

- I. biflora** Walt. Spotted Touch-me-not. Moist shady places; common.
- I. pallida** Nutt. Pale Touch-me-not. Moist shady places, especially on mountain sides.

RHAMNACEAE. BUCKTHORN FAMILY

CEANOTHUS. Red-root

- C. americanus** L. New Jersey Tea. Dry woodlands; common.
- C. ovatus** Desf. Sandy banks of Lake Champlain, Burlington.

RHAMNUS. Buckthorn

- R. alnifolia** L'Her. Dwarf Alder. Swamps; more frequent in western Vermont.
- R. cathartica*** L. Common Buckthorn. Common in cultivation and a frequent escape in woods and fields.

VITACEAE. VINE FAMILY

PSEDERA. (PARTHENOCISSUS). Woodbine. Virginia Creeper

- P. quinquefolia** (L.) Greene. Woodbine, American Ivy. Moist thickets; common.
- P. quinquefolia** (L.) Greene, var. **hirsuta** (Donn.) Rehder. Clinging closely to limestone ledges; Cornwall, (Brainerd); Burlington, (Jones); Rutland, (Kirk).
- P. vitacea** (Knerr) Greene. Woodbine. Alluvial thickets; common.

VITIS. Grape

- V. bicolor* LeConte. Summer Grape. Dry gravelly soil at bases of cliffs of the lower altitudes; frequent.
V. labrusca L. Northern Fox Grape. Vernon, (Grout).
V. vulpina L. River-bank or Frost Grape. River banks; common.

TILIACEAE. LINDEN FAMILY

TILIA. Linden

- T. americana* L. Basswood. Woodlands; common.

MALVACEAE. MALLOW FAMILY

ABUTILON. Indian Mallow

- A. Theophrasti** Medic. (*A. Abutilon* [L.] Rusby). Velvet Leaf. Roadsides and waste places; occasional.

HIBISCUS. Rose Mallow

- H. Trionum** L. Bladder Ketmia. Occasional as a garden weed. Middlebury, (Brainerd); Peacham, (Blanchard); Panton and Burlington, (Jones); Putney, (W. H. Blanchard).

MALVA. Mallow

- M. Alcea** L. European Mallow. Lyndon, (Congdon); Rutland, (Eggleston); Burlington, (Mrs. N. F. Flynn); Westminster and Wardsboro, (W. H. Blanchard); Hartland, (Underwood).
*M. moschata** L. Musk Mallow. Roadsides and waste places; an occasional escape.
*M. rotundifolia** L. Common Mallow, Cheeses. Waste places; everywhere common.
*M. sylvestris** L. High Mallow. Occurs sparingly in several places.
*M. verticillata** L. A garden weed, increasingly troublesome. Middlebury, (Brainerd); Burlington, (Jones). Var. *crispa** L. Curled Mallow. Knight's Island, (Brainerd).

HYPERICACEAE. ST. JOHN'S-WORT FAMILY

HYPERICUM. St. John's-wort

- H. Ascyron* L. Great St. John's-wort. River banks; occasional.
H. boreale (Britton) Bicknell. Wet soil; occasional.
H. canadense L. Moist soil; frequent.
H. ellipticum Hook. Pale St. John's-wort. Wet places of the lower altitudes; common.
H. gentianoides (L.) BSP. (*Sarothra gentianoides* L.). Orange Grass, Pine-weed. Brattleboro, (Frost, Grout); Dummerston, (Wheeler); Vernon, (W. H. Blanchard).
H. majus (Gray) Britton. (*H. canadense* L., var. Gray). Moist soil; occasional.

- H. mutilum** L. Low ground; common.
H. perforatum* L. Common St. John's-wort. Fields and roadsides; common.
H. punctatum Lam. (*H. maculatum* Walt.). Damp places of the lower altitudes; frequent.
H. virginicum L. (*Triadenum virginicum* Raf.). Marsh St. John's-wort. Swamps; frequent.

CISTACEAE. ROCK ROSE FAMILY

HELIANTHEMUM. (CROCANTHEMUM). Rock Rose

- H. canadense** (L.) Michx. Frostweed. Sandy soil; occasional.
H. majus BSP. Frostweed. Sterile soil; frequent.

HUDSONIA

- H. tomentosa** Nutt., var. **intermedia** Peck. False Heather, Poverty Grass. Sandy beaches of Lake Champlain. Burlington Bay, Colchester Point, (Bigelow); Apple Tree Bay, (Mrs. N. F. Flynn).

LECHEA. Pinweed

- L. intermedia** Leggett. Dry sterile soil of the lower altitudes; occasional.
L. minor L. Vernon, (W. H. Blanchard).
L. villosa Ell. Hairy Pinweed. Vernon, (B. L. Robinson).

VIOLACEAE. VIOLET FAMILY

VIOLA. Violet. Heart's-ease

- V. adunca** Sm. Sandy and sterile soil; occasional.
V. affinis Le Conte. Moist thickets and borders of streams; frequent.
V. blanda Willd. Sweet White Violet. Rich woodlands; frequent.
V. canadensis L. Canada Violet. Woodlands; common.
V. conspersa Reichenb. Dog Violet. Moist or shady ground; common.
V. cucullata Ait. Marsh Blue Violet. Wet places and at high altitudes; frequent.
V. eriocarpa Schwein. (*V. scabriuscula* Schwein.). Torr. Bull. 38: 194. Smooth Yellow Violet. Moist open woods; frequent.
V. fimbriatula Sm. Sandy fields and dry hillsides; frequent.
V. incognita Brainerd. Sweet White Violet. Low moist woodlands and mountain slopes, often at high altitudes; common.
V. incognita, var. **Forbesii** Brainerd. Moist woods; frequent.
V. lanceolata L. Lance-leaved Violet. Moist pastures and pond borders; rare. Rutland, (Eggleston); Manchester, (Mary A. Day); Lily Pond, Vernon, (Grout); Williston, (Bates); Townshend, (Wheeler).
V. latiuscula Greene. Dry open woods; occasional.
V. nephrophylla Greene. Cold bogs and borders of streams and lakes; occasional.

- V. pallens* (Banks) Brainerd. Sweet White Violet. Wet soil near springs and cold brooks, often at high altitudes; frequent.
- V. papilionacea* Pursh. Moist groves and fence rows; occasional.
- V. pubescens* Ait. Downy Yellow Violet. Dry rich woods; frequent.
- V. renifolia* Gray. Arbor-vitae swamps and cold woods; occasional.
- V. renifolia* Gray, var. *Brainerdii* (Greene) Fernald. Occasional.
- V. rostrata* Pursh. Long-spurred Violet. Shady hillsides; frequent.
- V. rotundifolia* Michx. Round-leaved or Early Yellow Violet. Cold woods; occasional.
- V. Selkirkii* Pursh. Great-spurred Violet. Shady ravines and cold mountain woods; occasional.
- V. septentrionalis* Greene. Moist open woods; frequent.
- V. sororia* Willd. Woolly Blue Violet. Moist meadows and shady ledges; common.
- V. tricolor** L. Pansy, Heart's-ease, Johnny-jump-up. Depauperate forms of the garden pansy sometimes occur spontaneously and are taken for this species. But the cultivated pansy is the result of frequent crossing of *V. tricolor* with allied species.
- V. triloba* Schwein. Dry rocky woodlands; Pownal, (Robbins); North Pownal, (Eggleston); Orwell, (Brainerd); West Haven, (Kirk).

Hybrids of *Viola* found in Vermont by Ezra Brainerd.:

- V. affinis* x *cucullata*. Rhod. 8: 49.
- V. affinis* x *nephrophylla*. Rhod. 8: 50.
- V. affinis* x *septentrionalis*. Rhod. 6: 219.
- V. affinis* x *sororia*. Rhod. 6: 221.
- V. conspersa* x *rostrata*. Ined. Middlebury.
- V. cucullata* x *fimbriatula*. Rhod. 6: 217.
- V. cucullata* x *nephrophylla*. Rhod. 8: 50.
- V. cucullata* x *septentrionalis*. Rhod. 6: 220.
- V. cucullata* x *sororia*. Rhod. 6: 222.
- V. fimbriatula* x *latiuscula*. Ined. Fort Ethan Allen, Colchester.
- V. fimbriatula* x *septentrionalis*. Rhod. 6: 215. Pl. 58.
- V. fimbriatula* x *sororia*. Rhod. 6: 218.
- V. latiuscula* x *sororia*. Ined. East Salisbury.
- V. nephrophylla* x *sororia*. Ined. Manchester.
- V. septentrionalis* x *sororia*. Rhod. 6: 221.
- V. sororia* x *triloba*. Bull. Torrey Bot. Club, 39: 82.

THYMELAEACEAE. MEZEREUM FAMILY

DAPHNE. Mezereum

- D. Mezereum** L. Garden escape; Bradford, (Alice Bacon); Burlington, (Jones).

DIRCA. Leatherwood. Moosewood

- D. palustris* L. Wicopy. Moist open woods; frequent.

ELAEAGNACEAE. OLEASTER FAMILY**SHEPHERDIA. (LEPARGYRAEA)**

- S. canadensis** (L.) Nutt. Red sandstone cliffs, western Vermont; occasional.

LYTHRACEAE. LOOSESTRIFE FAMILY**DECODON. Swamp Loosestrife**

- D. verticillatus** (L.) Ell. Water Willow. Swampy ground; occasional in western Vermont.

LYTHRUM. Loosestrife

- L. alatum** Pursh. Charlotte, (Pringle); Brandon, (Dutton); Burlington, (Mrs. N. F. Flynn).
L. Salicaria* L. Spiked Loosestrife. Wet meadows; Rutland, (Bigelow, Eggleston); Sharon, (Jesup, Sargent); Clarendon, (Grout); Wallingford, (Mrs. N. F. Flynn); West Haven, (Kirk).

MELASTOMACEAE. MELASTOMA FAMILY**RHEXIA. Deer-grass**

- R. virginica** L. Meadow Beauty. "Brattleboro," (Frost); Lily Pond, Vernon, (Grout).

ONAGRACEAE. EVENING PRIMROSE FAMILY**CIRCAEA. Enchanter's Nightshade**

- C. alpina** L. Deep woods; common.
C. intermedia Ehrh. Deep shade; occasional
C. lutetiana L. Woods; frequent.

EPILOBIUM. Willow-herb

- E. adenocaulon** Haussk. Moist places; frequent.
E. angustifolium L. (*Chamaenerion angustifolium* [L.] Scop.). Fireweed, Great Willow-herb. Common, especially in newly cleared lands.
E. coloratum Muhl. Wet places; occasional.
E. densum Raf. (*E. lineare* Muhl.?). Bogs; common.
E. molle Torr. (*E. strictum* Muhl.?). Cold bogs; occasional.
E. palustre L. Bogs of northern Vermont; rare. Franklin, (Underwood).
E. palustre L., var. *monticola* Haussk. (*E. lineare*, var. *oliganthum* Trel.). Bogs; Stratton, (Grout); Sunderland and Mendon, (Eggleston); Rutland, (Kirk).

LUDVIGIA. (ISNARDIA). False Loosestrife

- L. palustris** (L.) Ell. Water Purslane. Ditches and swamps of the lower altitudes; common.

OENOTHERA. Evening Primrose

- O. biennis* L. Common Evening Primrose. Dry soil; occasional.
- O. cruciata* Nutt. Gravelly soil; occasional.
- O. laciniata* Hill. (*Raimannia laciniata* [Hill] Rose). Fort Ethan Allen, (Grout); Burlington, (Mrs. N. F. Flynn).
- O. muricata* L. (*O. biennis* L. in part). Sandy soil of the lower altitudes; common.
- O. Oakesiana* Robbins. Adventive by roadsides, Burlington, (Hazen).
- O. pratensis* (Small) Robinson. (*Kneiffia pratensis* Small). Hartland, (Nancy Darling).
- O. pumila* L. (*Kneiffia pumila* [L.] Spach.). Fields; common.
- O. serrulata* Nutt. (*Meriolix serrulata* [Nutt.] Walp.). Along railroad, Burlington, (Mrs. N. F. Flynn).

HALORAGIDACEAE. WATER MILFOIL FAMILY

HIPPURIS. Mare's-tail

- H. vulgaris* L. Rare; in cold springy margin of Joe's Pond, West Danville, (Blanchard); Willoughby Lake, (Kennedy).

MYRIOPHYLLUM. Water Milfoil

- M. alterniflorum* DC. Bay south of North Hero, (Pringle and Brainard).
- M. Farwellii* Morong. Mountain ponds. Belden's Pond, Johnson; Townshend, (Grout); Spectacle Pond, Wallingford; North Pond, Brunswick; Little Averill Pond, (Eggleston).
- M. humile* (Raf.) Morong. Water Milfoil. West River, West Townshend, (Grout).
- M. spicatum* L. In deep water; common.
- M. tenellum* Bigel. Borders of ponds; occasional.

PROSERPINACA. Mermaid-weed

- P. palustris* L. Swamps of the lower altitudes of western Vermont; occasional. Fairlee Lake, (Jesup and Sargent).

ARALIACEAE. GINSENG FAMILY

ARALIA. Wild Sarsaparilla

- A. hispida* Vent. Bristly Sarsaparilla, Wild Elder. Rocky or sandy woodlands; frequent.
- A. nudicaulis* L. Wild Sarsaparilla. Moist woodlands; common.
- A. racemosa* L. Spikenard. Rich woodlands; frequent.

PANAX. Ginseng

- P. quinquefolium* L. Ginseng. Deciduous woods; becoming rare from much digging of the root.
- P. trifolium* L. Dwarf Ginseng, Ground-nut. Moist woods and thickets; common.

UMBELLIFERAE. PARSLEY FAMILY**ANGELICA.** Angelica

- A. atropurpurea** L. Masterwort, Purple Angelica. Swamps and moist grounds; frequent.

CARUM. Caraway

- C. Carvi*** L. About dwellings and roadsides; frequent.

CICUTA. Water Hemlock

- C. bulbifera** L. Water Hemlock. Wet places; common.
C. maculata L. Spotted Cowbane, Musquash Root, Beaver Poison. Wet places; common. The root is very poisonous.

CONIOSELINUM. Hemlock Parsley

- C. chinense** (L.) BSP. Swamps and cold cliffs; occasional.

CONIUM. Poison Hemlock

- C. maculatum*** L. Waste places; occasional.

CRYPTOTAENIA. (DERINGA). Honewort

- C. canadensis** (L.) DC. Moist woods; common.

DAUCUS. Carrot

- D. Carota*** L. Wild Carrot. Old meadows; common.

HERACLEUM. Cow Parsnip. Masterwort

- H. lanatum** Michx. Cold moist ground; frequent.

HYDROCOTYLE. Water Pennywort

- H. americana** L. Wet places; common.

LEVISTICUM. Lovage

- L. officinale*** (L.) Koch. Occasionally adventive.

OSMORHIZA. (WASHINGTONIA). Sweet Cicely

- O. Claytoni** (Michx.) Clarke. Sweet Cicely. Rich woods; common.
O. longistylis (Torr.) DC. Sweet Cicely, Anise-root. Moist rich woods of the lower altitudes; occasional.

PASTINACA. Parsnip

- P. sativa*** L. Wild Parsnip. Roadsides and waste places; common.

SANICULA. Black Snakeroot. Sanicle

- S. canadensis** L. Shaded ledges of the lower altitudes of western Vermont; frequent.
S. gregaria Bicknell. Moist rich soil of the lower altitudes; frequent; Norwich, (Eggleston).
S. marilandica L. Moist woods; common.
S. trifoliata Bicknell. Rich woods of the lower altitudes of western Vermont; frequent.

SIUM. Water Parsnip

S. cicutaeifolium Schrank. Wet places of the lower altitudes; frequent.

TAENIDIA

T. integerrima (L.) Drude. Yellow Pimpernel. Ledges in the Champlain Valley; occasional.

ZIZIA

Z. aurea (L.) Koch. Golden Alexanders, Golden Meadow Parsnip. Moist meadows; common.

CORNACEAE. DOGWOOD FAMILY

CORNUS. Cornel. Dogwood

C. alternifolia L. f. Dogberry. Open woods; common.

C. Amomum Mill. (*C. sericea* L.). Kinnikinnik, Silky Cornel. Low woods and banks of the lower altitudes; common.

C. canadensis L. (*Chamaepericlymenum canadense* [L.] Asch. & Graebn.). Bunch-berry, Dwarf Cornel. Cold damp woods; common.

C. circinata L'Her. (*C. rugosa* Lam.). Round-leaved Cornel. Rocky woodlands; frequent.

C. florida L. (*Cynoxylon floridum* [L.] Raf.). Flowering Dogwood. Dry woods of southern Vermont; occasional.

C. paniculata L'Her. (*C. femina* Mill.; *C. candidissima* Marsh.). Panicked Dogwood. Rich thickets and banks; frequent.

C. stolonifera Michx. Red-osier Dogwood. Wet places; common.

NYSSA. Tupelo. Pepperidge. Sour Gum

N. sylvatica Marsh. Black Gum, Tupelo. Rich soil, generally swampy; occasional.

ERICACEAE. HEATH FAMILY

ANDROMEDA

A. glaucophylla Link. (*A. Polifolia* mostly of Am. auth., not L.). Bog Rosemary. Boggy margins of ponds; frequent.

ARCTOSTAPHYLOS. (UVA-URSI). Bearberry

A. Uva-ursi (L.) Spreng. Cliffs and bare hills of western Vermont and south in the Connecticut Valley to Fairlee Cliffs; occasional.

CHAMAEDAPHNE. Leather Leaf. Cassandra

C. calyculata (L.) Moench. Bogs; frequent.

CHIMAPHILA. Pipsissewa

C. maculata (L.) Pursh. Spotted Wintergreen. Dry woods; Newfane, (Grout).

C. umbellata (L.) Nutt. Prince's Pine, Pipsissewa. Dry woods; common.

CHIOGENES. Creeping Snowberry

C. hispida (L.) T. & G. Moxie Plum, Capillaire. Peat bogs and mossy woods; frequent.

EPIGAEA. Ground Laurel. Trailing Arbutus

E. repens L. Mayflower. Sandy or rocky woodlands; common in certain areas.

GAULTHERIA. Aromatic Wintergreen

G. procumbens L. Teaberry, Checkerberry. Cool woods; common.

GAYLUSSACIA. Huckleberry

G. baccata (Wang.) K. Koch. Black Huckleberry. Sterile fields and thickets of western Vermont, and north in the Connecticut Valley to Hartford; common. *Forma glaucocarpa* (Robinson) Mackenzie. Blue Huckleberry. Westminster and Pownal, (W. H. Blanchard); Colchester and Burlington, (Blake).

KALMIA. Laurel

K. angustifolia L. Sheep Laurel, Lambkill, Wicky. Sterile fields and peat bogs; frequent.

K. latifolia L. Mountain Laurel, Calico Bush, Spoon-wood. Rocky hills; Rockingham, (Carey); Pownal, (Eggleston). Common along banks of West River between Brattleboro and Newfane and along the Connecticut River from Rockingham to Vernon, (W. H. Blanchard).

K. polifolia Wang. Pale Laurel. Peat bogs; occasional.

LEDUM. Labrador Tea

L. groenlandicum Oeder. Cold bogs; frequent.

LYONIA. (XOLISMA)

L. ligustrina (L.) DC. (*Andromeda ligustrina* Muhl.). Male Berry. Occasional in southern Vermont.

MONESES. One-flowered Pyrola

M. uniflora (L.) Gray. Deep cold woods; occasional.

MONOTROPA. Indian Pipe. Pinesap

M. Hypopitys L. (*Hypopitys lanuginosa* [Michx.] Nutt.). Pinesap. False Beech Drops. Rich dry woods; occasional.

M. uniflora L. Indian Pipe, Corpse Plant. Dark rich woods; common.

PTEROSPORA. Pine Drops

P. andromeda Nutt. Pine woods; rare.

PYROLA. Wintergreen. Shin Leaf

P. americana Sweet. (*P. rotundifolia* Gray's Man., ed. 6). Round-leaved Shin Leaf. Sandy woodlands of the lower altitudes; occasional.

- P. asarifolia** Michx. Alluvial woods; Norwich, (Eggleston); Westmore, (Kennedy); Clarendon and Rutland, (Kirk).
P. asarifolia Michx., var. **incarnata** (Fisch.) Fernald. Sphagnum bogs; occasional.
P. chlorantha Sw. Dry woods; frequent.
P. elliptica Nutt. Shin Leaf. Rich woods; common.
P. minor L. Smugglers' Notch, (Pringle); Killington Mt., Sherburne, (Kirk); rare.
P. secunda L. Rich woods; frequent.
P. secunda L., var. **obtusata** Turcz. Peat bogs; Bristol Pond bog, (Pringle); Sutton and Newark, (E. Faxon); cedar swamp, Fairhaven, (Eggleston); Brandon, (Dutton).

RHODODENDRON

- R. canadense** (L.) BSP. Rhodora. Swamps and damp slopes of northern Vermont; occasional.
R. canescens (Michx.) G. Don. (*Azalea canescens* Michx.). Pinxter Flower. Woody banks and gravelly shores; occasional.
R. maximum L. Great Laurel. Rocky woods bordering Groton Pond, (Perkins); Peacham, (Blanchard); Martin's and Niggerhead Ponds, (Burbank); Lanesboro, (Miss M. Skinner); Harvey's Pond, West Barnet, (Marion Bole and Mrs. M. B. Hale).

VACCINIUM. Blueberry. Cranberry

- V. atrococcum** (Gray) Heller. Black High Blueberry. Swamps and pond borders of the lower altitudes of western Vermont; occasional.
V. caespitosum Michx. Dwarf Bilberry. Mt. Mansfield Chin, (Pringle); rocky shore West River, Newfane, (Grout); Townshend, (Wheeler); Jamaica, (Dobbin); Deerfield River, Wilmington, (W. H. Blanchard).
V. canadense Kalm. Sour-top or Velvet-leaf Blueberry. Moist thickets; common in the mountains. The market blueberry of Essex County.
V. corymbosum L. High or Swamp Blueberry. Swamps and low thickets. The abundant blueberry about northern Lake Champlain.
V. corymbosum L., var. **amoenum** (Ait.) Gray. Swamps; Monkton and Charlotte, (Pringle).
V. corymbosum L., var. **pallidum** (Ait.) Gray. Occasional.
V. macrocarpon Ait. (*Oxycoccus macrocarpon* [Ait.] Pursh.). Large or American Cranberry. Peat bogs; frequent.
V. Oxycoccus L. (*Oxycoccus Oxycoccus* [L.] MacM.). Small Cranberry. Cold peat bogs; frequent.
V. Oxycoccus L., var. **ovalifolium** Michx. (var. *intermedium* Gray). Rhod. 11:54. Occurs rarely. Colchester, (Oakes); Willoughby Lake, (Kennedy).
V. pennsylvanicum Lam. (*V. angustifolium* Ait.). Low Sweet or Early Sweet Blueberry. Dry hills of the lower altitudes; common. The earliest market blueberry. Var. *angustifolium* (Ait.) Gray. Summit of Mt. Mansfield and Camel's Hump, (Robbins, Pringle).

- V. pennsylvanicum** Lam., var. **nigrum** Wood. (*V. nigrum* [Wood] Britton). Low Black Blueberry. Occasional with type.
- V. pennsylvanicum** Lam., var. **myrtilloides** (Michx.) Fernald. Rhod. 10: 147. East Wallingford, (Kent); Essex Junction, (Blake).
- V. uliginosum** L. Bog Bilberry. Summit of Mt. Mansfield and Camel's Hump, (Robbins, Pringle); Johnson, (Grout).
- V. uliginosum** L., var. **pubescens** Lange. Rhod. 15: 201. Mt. Mansfield, Jay Peak, Johnson, (Blake).
- V. vacillans** Kalm. Late Low Blueberry. Dry woodlands; common. Forming part of the later blueberries of the market.
- V. vacillans** Kalm., var. **crinitum** Fernald. Rhod. 13: 235. Rutland, the type station, and West Haven, (Kirk).
- V. Vitis-Idaea** L., var. **minus** Lodd. (*Vitis-Idaea Vitis-Idaea* [L.] Britton). On the summits of Mt. Mansfield and Camel's Hump, (Robbins); Willoughby Mt., (Kennedy).

DIAPENSIACEAE. DIAPENSIA FAMILY

DIAPENSIA

- D. lapponica** L. Mt. Mansfield Chin, (Pringle).

PRIMULACEAE. PRIMROSE FAMILY

ANAGALLIS. Pimpernel

- A. arvensis*** L. Common Pimpernel, Poor Man's Weather-glass. Lawns; Bradford, (Alice E. Bacon); Townshend, (W. H. Blanchard); Norwich, (H. B. Olds). Var. **caerulea*** (Schreb.) Ledeb. Bradford, (Alice E. Bacon); Middletown, (Carpenter).

LYSIMACHIA. Loosestrife

- L. Nummularia*** L. Moneywort, Yellow Myrtle. Lawns and damp ground; occasional.
- X L. producta** (Gray) Fernald. (*L. quadrifolia* x *terrestris*). Mouth of the Winooski River, (Eggleston and Jones); Jamaica, (Underwood).
- L. quadrifolia** L. Dry thickets of the lower altitudes; common.
- L. terrestris** (L.) BSP. Low ground; common.
- L. thyrsoiflora** L. Tufted Loosestrife. Bogs and swamps; frequent.

PRIMULA. Primrose. Cowslip

- P. mistassinica** Michx. Willoughby Mountain, (A. Wood); Smugglers' Notch, (Morong).

SAMOLUS. Water Pimpernel. Brook-weed

- S. floribundus** HBK. Along sluggish brooks; Middlebury, (James, C. N. Brainerd); "Brattleboro," (Frost).

STEIRONEMA

- S. ciliatum* (L.) Raf. Moist thickets; common.
S. lanceolatum (Walt.) Gray. Low grounds along northern Lake Champlain; occasional.

TRIENTALIS. Chickweed Wintergreen

- T. borealis* Raf. (*T. americana* [Pers.] Pursh). Rhod. 11: 236. Star Flower. Moist woods and thickets; common.

OLEACEAE. OLIVE FAMILY

FRAXINUS. Ash

- F. americana* L. White Ash. Rich woods; common.
F. nigra Marsh. Black Ash. Swamps and wet woods; common.
F. pennsylvanica Marsh. Red Ash. Low grounds; common along Lake Champlain and its tributaries. Newport, (C. H. Knowlton).
F. pennsylvanica Marsh., var. *lanceolata* (Borkh.) Sarg. Green Ash. Occasional along shores of Lake Champlain. Walpole, N. H., (Fernald).

SYRINGA. Lilac

- S. vulgaris** L. Common Lilac. An escape from cultivation.

GENTIANACEAE. GENTIAN FAMILY

BARTONIA

- B. virginica* (L.) BSP. "Rockingham," (Carey); Higbee swamp, South Burlington, (Jones); Colchester, (Mrs. N. F. Flynn).

GENTIANA. Gentian

- G. Amarella* L., var. *acuta* (Michx.) Herder. (*G. acuta* Michx.). Smugglers' Notch, (Pringle).
G. Andrewsii Griseb. (*Dasystephana Andrewsii* [Griseb.] Small). Closed Gentian. Moist grounds of the lower altitudes; frequent.
G. crinita Froel. Fringed Gentian. Moist ground; frequent in the southern part of the State.
G. linearis Froel. (*Dasystephana linearis* [Froel.] Britton). Bogs and meadows in the mountains; occasional.
G. quinquefolia L. Moist hills; occasional.

HALENIA. Spurred Gentian

- H. deflexa* (Sm.) Griseb. Banks of Lewis Creek, Charlotte, (Horsford and Pringle); St. Johnsbury, (Inez A. Howe).

MENYANTHES. Buckbean

- M. trifoliata* L. Bog Bean, Marsh Trefoil. Sphagnum bogs; occasional.

NYMPHOIDES. (LIMNANTHEMUM). Floating Heart

N. lacunosum (Vent.) Fernald. Shallow water; Spectacle Pond, East Wallingford, (Kent); Springfield, (Eggleston); common in Windham County, (Grout).

APOCYNACEAE. DOGBANE FAMILY

APOCYNUM. Dogbane. Indian Hemp

- A. androsaemifolium** L. Spreading Dogbane. Thickets and fields; common.
A. cannabinum L. Indian Hemp. Moist banks; occasional.
A. medium Greene. Willoughby Lake, (Kennedy); rocky shore of Winooski River near High Bridge, Essex, (Blake).

VINCA. Periwinkle

- V. minor*** L. Common Periwinkle, Blue Myrtle. Persisting in neglected dooryards.

ASCLEPIADACEAE. MILKWEED FAMILY

ASCLEPIAS. Milkweed. Silkweed

- A. amplexicaulis** Sm. (*A. obtusifolia* Michx.). Sandy soil; frequent about Burlington.
A. incarnata L. Swamp Milkweed. Marshes of the lower altitudes; common.
A. incarnata L., var. **pulchra** (Ehrh.) Pers. (*A. pulchra* Ehrh.). Swamp Milkweed. Dummerston, (Addie L. Reed); Jamaica, (Wheeler).
A. phytolaccoides Pursh. (*A. exaltata* Muhl.). Poke Milkweed. Moist copses of the lower altitudes; occasional.
A. quadrifolia Jacq. Rocky woods of the lower altitudes; occasional.
A. syriaca L. Common Milkweed or Silkweed. Rich grounds; common.
A. tuberosa L. Butterfly Weed. Dry fields; "Pownal," (Robbins); Belows Falls, (Carey, W. H. Blanchard); Vernon, (Grout); Manchester, (Mary A. Day); Brattleboro, (Addie L. Reed).

CYNANCHUM

- C. nigrum*** (L.) Pers. Black Swallow-wort. Brattleboro, (Frost); Windsor, (Leland); Hartland, (Underwood).

CONVOLVULACEAE. CONVOLVULUS FAMILY

CONVOLVULUS. Bindweed

- C. arvensis*** L. Field Bindweed. A garden weed; Woodstock, (Dana); Burlington, (Jones); Rutland, (Kirk); becoming common.
C. japonicus* Thunb. California Rose. The double-flowered form is an occasional escape from cultivation.

- C. sepium* L. Hedge Bindweed. Moist thickets; common.
C. sepium L., var. *pubescens* (Gray) Fernald. Along gravelly shores of Lake Champlain; occasional.
C. spithameus L. Dry sandy plains; common about Burlington. Norwich and Rutland, (Eggleston).

CUSCUTA. Dodder. Love Vine

- C. Epithymum** Murr. In clover fields; threatening to become troublesome.
C. Gronovii Willd. Moist thickets of the lower altitudes; common.

IPOMOEAE. (QUAMOCLIT). Morning Glory

- I. coccinea* L., var. *hederifolia** (L.) Gray. In garden, Burlington, (Mrs. Zottman).
I. purpurea (L.) Roth. Common Morning Glory. Frequently spontaneous in gardens and waste places.

POLEMONIACEAE. POLEMONIUM FAMILY

GILIA. (COLLOMIA)

- G. linearis* (Nutt.) Gray. Railroad yards, Burlington, (Mrs. N. F. Flynn).

PHLOX

- P. divaricata* L. Blue Phlox. Sheldon, (Underwood).
P. maculata L. Wild Sweet William. Hancock, (Dutton).
P. paniculata L. Garden Phlox. Garden escape; common.
P. stolonifera Sims. Middletown Springs, (Carpenter); Stowe, (Mrs. Carrie E. Straw).
P. subulata L. Ground or Moss Pink. Old cemeteries; St. Johnsbury, (Isabella M. Paddock); Putney and Stratton, (W. H. Blanchard); on rocky hill, Colchester, (Griffin).

POLEMONIUM. Greek Valerian

- P. Van-Bruntiae* Britton. Abby Pond, Ripton, (Brainerd); Cavendish, (Underwood).

HYDROPHYLLACEAE. WATERLEAF FAMILY

HYDROPHYLLUM. Waterleaf

- H. canadense* L. Damp rich woods; Pownal, (Churchill).
H. virginianum L. Rich woods of the lower altitudes; common.

BORAGINACEAE. BORAGE FAMILY

CYNOGLOSSUM. Hound's Tongue

- C. boreale* Fernald. Wild Comfrey. Moist banks of the lower altitudes; occasional. Peacham, (Blanchard); Fairlee, (Sargent and Eggleston).

C. officinale* L. Common Hound's-tongue. Pastures; frequent.

ECHIUM. Viper's Bugloss

E. vulgare* L. Blueweed, Blue Devil. Pastures and moist soil. Becoming increasingly troublesome as a weed, particularly in Rutland County and southward.

LAPPULA. Stickseed

L. echinata* Gilibert. (*Lappula lappula* [L.] Karst.). Ledges and gravelly shores of Lake Champlain; frequent.

L. virginiana (L.) Greene. Beggar's Lice. Borders of woods in the lower altitudes; frequent.

LITHOSPERMUM. Gromwell. Puccoon

L. arvense L. Common Gromwell. Old fields and roadsides of western Vermont; occasional.

L. latifolium Michx. Colchester, (Griffin).

L. officinale* L. Common Gromwell. Dry pastures; common.

MERTENSIA. Lungwort

M. virginica (L.) Link. Virginia Cowslip, Bluebells. Garden escape, Burlington, (Gifford).

MYOSOTIS. Forget-me-not. Scorpion-grass

M. arvensis (L.) Hill. Sharon, (Dr. Baxter); Townshend, (W. H. Blanchard).

M. laxa Lehm. Wild Forget-me-not. Cold brooks; Peacham, (Blanchard); abundant in White River Valley, (Eggleston).

M. scorpioides L. (*M. palustris* Hill). True Forget-me-not. Frequently naturalized along cold brooks.

M. virginica (L.) BSP. (*M. verna* Nutt.). Dry banks and ledges; occasional.

SYMPHYTUM. Comfrey

S. aspernum* Donn. Rough Comfrey. Dummerston, Vernon, (W. H. Blanchard); Stockbridge, Rutland, (Eggleston).

S. officinale* L. Common Comfrey. Moist places; occasional.

VERBENACEAE. VERVAIN FAMILY

VERBENA. Vervain

V. angustifolia Michx. Arlington, (W. H. Blanchard).

V. hastata L. Blue Vervain. Roadsides of the lower altitudes; common.

V. urticaefolia L. White Vervain. Roadsides of the lower altitudes; common.

X V. hastata x urticaefolia. Pownal, (W. H. Blanchard); Rutland, (Kirk).

LABIATAE. MINT FAMILY

AGASTACHE. (LOPHANTHUS). Giant Hyssop

- A. nepetoides* (L.) Ktze. Thickets and along fences; Middlebury, (James, Brainerd); Pownal, Bennington, Arlington, (Robbins); Stowe, (Mrs. Carrie E. Straw).
A. scrophulariaefolia (Willd.) Ktze. Thickets and fencerows of western Vermont; occasional. South Newbury, (Jesup and Sargent).
 Var. *mollis* (Fernald) Heller. Manchester, (Mary A. Day).

AJUGA. Bugle Weed

- A. genevensis** L. In lawn, Burlington, (Jones).

BLEPHILIA

- B. ciliata* (L.) Raf. Wood Mint. Dry open places; East Dorset, (S. Grout); Manchester, (Mary A. Day).
B. hirsuta (Pursh.) Benth. Wood Mint. Moist shady places in the mountains; occasional. Var. *glabrata* Fernald. Dry soil; Manchester, (Mary A. Day).

COLLINSONIA. Horse Balm

- C. canadensis* L. Rich-weed, Stone-root. Rich moist woods of southern and central Vermont; occasional west of the mountains. (Middlebury, (James); Arlington, (Robbins); Proctor, (Brainerd).

GALEOPSIS. Hemp Nettle

- G. Tetrahit** L. Common Hemp Nettle. Waste places; common.

HEDEOMA. Mock Pennyroyal

- H. hispida* Pursh. Burlington, (Hollister); Rutland, (Kirk); Colchester, (Griffin); Essex, (Blake).
H. palegioides (L.) Pers. American Pennyroyal. Dry fields; common.

HYSSOPUS. Hyssop

- H. officinalis** L. Roadsides and fields; occasional.

ISANTHUS. False Pennyroyal

- I. brachiatus* (L.) BSP. Dry sterile fields of southern and central Vermont, west of the mountains; rare.

LAMIUM. Dead Nettle

- L. amplexicaule** L. Henbit. Garden weed; Bristol, (Pringle); Rutland, (Eggleston); South Burlington, (Mrs. N. F. Flynn); Westminster, (W. H. Blanchard).
*L. maculatum** L. Spotted Dead Nettle, Flowering Sage. Garden escape; occasional. The white-flowered form occurs with the type, Essex, (Mrs. N. F. Flynn).

LEONURUS. Motherwort

- L. Cardiaca** L. Common Motherwort. Waste places; common.

LYCOPUS. Water Horehound

L. americanus Muhl. Moist soil; common.

L. uniflorus Michx. Bugle Weed. Shady moist places; common.

MARRUBIUM. Horehound

M. vulgare* L. Common Horehound. Garden escape; Peacham, (Blanchard); Brandon, (Dutton).

MENTHA. Mint

M. arvensis L. Field Mint. Willoughby Lake, (Kennedy); Hartland, (Underwood).

M. arvensis L., var. **canadensis** (L.) Briquet. Wild Mint. Wet places; common. Var. **lanata** Piper. Rutland, (Kirk).

M. arvensis L., var. **glabrata** (Benth.) Fernald. Hartland, (Underwood).

M. Cardiaca* Gerarde. Garden escape, Rutland, (Kirk).

M. gentilis* L. Spotted or Whorled Mint. Garden escape, Rochester and Rutland, (Eggleston); Johnson, (Grout); Burlington, (Mrs. N. F. Flynn); Stowe, (Mrs. Carrie E. Straw).

M. piperita* L. Peppermint. Along brooks; frequent.

M. spicata* L. (*M. viridis* L.) Spearmint. Moist places; common.

MONARDA. Horse-Mint

M. didyma L. Oswego Tea, Bee Balm. Moist woods; occasional.

M. fistulosa L., var. **rubra** Gray. Wild Bergamot. Garden escape, Stowe, Bennington, (Eggleston); Rutland, (Kirk).

M. mollis L. Downy Bergamot. Dry open woods; occasional.

M. punctata L. Horse Mint. Colchester and Burlington, (Mrs. N. F. Flynn); Essex, (Jones); St. Johnsbury and Vershire, (Inez A. Howe).

NEPETA. Cat Mint

N. Cataria* L. Catnip. Dry pastures; common.

N. hederacea* (L.) Trevisan. (*Glechoma hederacea* L.). Gill-over-the-Ground, Ground Ivy. Moist shady places; common.

ORIGANUM. Wild Marjoram

O. vulgare* L. Rocky soil; occasional.

PHYSOSTEGIA. (DRACOCEPHALUM). False Dragon Head

P. virginiana (L.) Benth. Lion's Heart. Gravelly shores of Lake Champlain; occasional.

PRUNELLA. (BRUNELLA). Self Heal

P. vulgaris L. Heal-all, Carpenter-weed. Woods and fields; common. Plants with white flowers occur occasionally.

PYCNANTHEMUM. (KOELLIA). Mountain Mint. Basil

P. flexuosum (Walt.) BSP. Dry fields of western Vermont; occasional. Hartland, (J. P. Webster).

- P. ineanum* (L.) Michx. Rocky woods; Pownal, (Robbins); Brattleboro and North Pownal, (Eggleston).
P. muticum (Michx.) Pers. Fields; Cavendish, (Macrae); Royalton, (Ward); South Shaftsbury, (Eggleston).
P. verticillatum (Michx.) Pers. Moist fields; occasional in western Vermont, common about Rutland, (Eggleston).
P. virginianum (L.) Durand & Jackson. Dry woods; occasional in western Vermont and in the Connecticut Valley north to Bellows Falls, (Carey, W. H. Blanchard).

SALVIA. Sage

- S. verticillata** L. Introduced in meadow, Dorset, (Mrs. Terry).

SATUREJA. (CLINOPODIUM). Savory. Calamint

- S. Acinos** (L.) Scheele. Burlington, (Mrs. N. F. Flynn); Townshend, (W. H. Blanchard); Rochester, (Dutton).
*S. hortensis** L. Summer Savory. Gravelly bank, outlet of Dorset Pond, (Grout); garden escape, Burlington, (Mrs. Jane Walker).
S. vulgaris (L.) Fritsch. Basil. Dry woods and thickets; frequent.

SCUTELLARIA. Skullcap

- S. galericulata* L. Marsh Skullcap. Wet shady places; common.
S. lateriflora L. Mad-dog Skullcap. Wet shady places; common.
S. parvula Michx. Dry banks and headlands of Lake Champlain; local.

STACHYS. Hedge Nettle

- S. palustris* L. Woundwort. Meadow, East Wallingford, (E. C. Kent).
S. tenuifolia Willd., var. *aspera* (Michx.) Fernald. Moist ground of the lower altitudes and north in the Connecticut Valley to Norwich; occasional.

TEUCRIUM. Germander

- T. occidentale* Gray. Rutland, (Eggleston).
T. occidentale Gray, var. *boreale* (Bicknell) Fernald. (*T. boreale* Bicknell). Rocky shores of Lake Champlain and the Connecticut River; occasional.

THYMUS. Thyme

- T. Serpyllum** L. Creeping Thyme. Peacham, (Blanchard); West Berkshire, (Wild, Mrs. Frances Jolley); South Hero, (Rugg).

TRICHOSTEMA. Blue Curls.

- T. dichotomum* L. Bastard Pennyroyal. Sandy fields of the lower altitudes; occasional. North in the Connecticut Valley to Norwich.

SOLANACEAE. NIGHTSHADE FAMILY

DATURA. Jamestown or Jimson Weed. Thorn Apple

- D. Stramonium** L. Stramonium, Thorn Apple. Occasional in waste places.
*D. Tatula** L. Purple Stramonium or Thorn Apple. Rare.

HYOSCYAMUS. Henbane

- H. niger*** L. Black Henbane. Roadsides; "Panton," (Burge); "Mt. Independence," (Dr. Hill); Shoreham, (Brainerd).

LYCIUM. Matrimony Vine

- L. halimifolium*** Mill. Common Matrimony Vine. Waste place, Burlington, (Mrs. N. F. Flynn).

NICANDRA. (PHYSALODES). Apple of Peru

- N. Physalodes*** (L.) Pers. Thetford and Peacham, (Blanchard); Shoreham and Woodstock, (Brainerd); Rutland, (Kirk); Burlington, (F. A. Ross).

PHYSALIS. Ground Cherry

- P. grandiflora** Hook. (*Leucophysalis grandiflora* [Hook] Rydberg). Providence Island, (Perkins); Stave Island, (Mrs. N. F. Flynn); South Hero, (J. H. Stickney).
- P. heterophylla** Nees. Manchester, (Mary A. Day); Willoughby Lake, (Kennedy); Hartland, (P. W. Whiting); Colchester, (Mrs. Jane Walker); St. Johnsbury, (Bridget M. Rooney). Var. **ambigua** (Gray) Rydberg. Sandy soil and gardens of the lower altitudes; occasional.
- P. peruviana*** L. Bank of Winooski River, Burlington, (Jones).
- P. pruinosa** L. Strawberry Tomato. Rutland, (Eggleston); Pittsford, (Grace A. Woolson); Middlebury, (Brainerd).
- P. subglabrata** Mackenzle & Bush. Colchester, (Mrs. Jane Walker).
- P. virginiana** Mill. Highgate, (Jesup); St. Johnsbury, (Mrs. M. H. Buckham).

SOLANUM. Nightshade

- S. carolinense** L. Horse Nettle. Woodstock, (Wild); Westminster, (W. H. Blanchard).
- S. Dulcamara*** L. Bittersweet, Woody Night-shade. Moist thickets of the lower altitudes; frequent.
- S. nigrum** L. Common Night-shade. Moist shaded ground of the lower altitudes; frequent.
- S. rostratum*** Dunal. Sand Bur, Buffalo Bur. Barre, (Eunice D. Smith); Burlington, (Helyer).

SCROPHULARIACEAE. FIGWORT FAMILY

CASTILLEJA. Painted Cup

- C. pallida** (L.) Spreng., var. **septentrionalis** (Lindl.) Gray. (*C. acuminata* (Pursh.) Spreng.). Mt. Mansfield, (Tuckerman and Macrae); Smugglers' Notch, (Pringle).

CHELONE. Turtlehead. Snakehead

- C. glabra** L. Balmony. Moist soil; common.

GERARDIA. Gerardia

- G. flava* L. (*Dasystoma flava* [L.] Wood). Downy False Foxglove. Bellows Falls, (Carey, W. H. Blanchard); Pownal, (Andrews); West Rutland, (Eggleston); Putney, Westminster, (W. H. Blanchard); Townshend, (Wheeler).
- G. paupercula* (Gray) Britton. (*Agalinis paupercula* [Gray] Britton). Knight's and Butler's Islands, (Brainerd); Highgate, (Wild); Colchester, (Mrs. N. F. Flynn, Griffin); Swanton, (Blake).
- G. pedicularia* L. (*Dasystoma pedicularia* [L.] Benth.). Dry copses of southern and central Vermont; occasional.
- G. tenuifolia* Vahl. (*Agalinis tenuifolia* [Vahl.] Raf.). Slender Gerardia. Dry open woods of the lower altitudes. North in the Connecticut Valley to Hartland and in western Vermont to Swanton.
- G. virginica* (L.) BSP. (*Dasystoma virginica* [L.] Britton). Smooth False Foxglove. Dry open woods of the lower altitudes of southern and central Vermont.

GRATIOLA. Hedge Hyssop

- G. aurea* Muhl. Sandy shores of Lake Champlain; rare. Rochester, (Dutton); Lily Pond, Vernon, (W. H. Blanchard); Hartland, (Underwood).
- G. virginiana* L. Wet shores and ditches of the lower altitudes of western Vermont; occasional.

ILYSANTHES. False Pimpernel

- I. dubia* (L.) Barnhart. Wet places; occasional.

LINARIA. Toadflax

- L. canadensis* (L.) Dumont. Blue Toadflax. Dry soil; Bellows Falls, (Carey, W. H. Blanchard). Vernon, (Grout); Westminster, South Vernon, (W. H. Blanchard); Jamaica, (Wheeler).
- L. minor** (L.) Desf. (*Chaenorhinum minus* [L.] Lange). Along railroad track, West Rutland, (Kirk); Sheldon, (Underwood); Swanton, (Blake).
- L. vulgaris** Hill. (*L. Linaria* [L.] Karst.). Ramsted, Butter and Eggs. Fields; common.

MELAMPYRUM. Cow Wheat

- M. lineare* Lam. Dry woodlands of the lower altitudes; frequent.

MIMULUS. Monkey Flower

- M. laevis** Donn. Yellow Monkey Flower. Reading, (Whiting).
- M. moschatum* Dougl. Musk-plant. Wet places; Wallingford, (Kent); Wardsboro, (Howe); Weston, (Mrs. N. F. Flynn); Jay, (Underwood).
- M. ringens* L. Wet places; common.

PEDICULARIS. Lousewort

P. canadensis L. Common Lousewort, Wood Betony. Thickets of the lower altitudes; common.

PENTSTEMON. Beard-tongue

P. hirsutus (L.) Willd. Rocky hills; frequent in western Vermont.

P. laevigatus Ait., var. *Digitalis* (Sweet) Gray. (*P. Digitalis* [Sweet] Nutt.). Fields; occasional.

RHINANTHUS. Yellow Rattle

R. Crista-galli L. Field, Bennington, (Mrs. Terry).

SCROPHULARIA. Figwort

S. leperella Bicknell. Meadows and fence rows of the lower altitudes; occasional.

S. marilandica L. Figwort. Waste places of western Vermont; occasional.

VERBASCUM. Mullein

*V. Blattaria** L. Moth Mullein. Clay or rocky pastures and roadsides; occasional. Var. *albiflorum** Ktze. Occasional with the type.

*V. Thapsus** L. Common Mullein. Fields; common.

VERONICA. Speedwell

V. americana Schwein. American Brooklime. Wet ground; common.

V. Anagallis-aquatica L. Water Speedwell. "Middlebury," (Burge); Timmouth Creek, Timmouth, (Eggleston).

*V. arvensis** L. Corn Speedwell. Fields; occasional.

*V. Chamaedrys** L. Bird's-eye. Glebe Mountain, Windham, (W. H. Blanchard).

V. humifusa Dickson. Peacham, (F. Blanchard); Willoughby Lake, (Kennedy); St. Johnsbury, (Isabelle M. Paddock).

V. officinalis L. Common Speedwell. Dry fields and thickets of the lower altitudes; common.

V. peregrina L. Neckweed, Purslane Speedwell. Gardens and waste places; frequent.

V. scutellata L. Marsh Speedwell. Wet grounds and marshes; common. North in the Connecticut Valley to Hanover, N. H.

V. serpyllifolia L. Thyme-leaved Speedwell. Roadsides and fields of the lower altitudes; common.

*V. Teucrium** L. East Wallingford, (E. C. Kent).

*V. Tournefortii** C. C. Gmel. (*V. Buxbaumii* Tenore). Waste ground; occasional.

LENTIBULARIACEAE. BLADDERWORT FAMILY

PINGUICULA. Butterwort

P. vulgaris L. Alpine cliffs, Smugglers' Notch, (Pringle).

UTRICULARIA. Bladderwort

- U. clandestina* Nutt. (*U. geminiscapa* Benj.). Willoughby Lake, (Kennedy).
U. cornuta Michx. (*Stomolisia cornuta* [Michx.] Raf.). Bogs; frequent.
U. gibba L. Rocky Pond, Rutland, (Ross).
U. inflata Walt. In still waters of southern Vermont; occasional.
U. intermedia Hayne. Shallow pools; occasional.
U. resupinata B. D. Greene. (*Lecticula resupinata* [B. D. Greene] Barnhart). Fairlee Lake, (Jesup and Sargent); Townshend, (Wheeler).
U. vulgaris L., var. *americana* Gray. (*U. macrorrhiza* Le Conte). Greater Bladderwort. Ponds and slow streams; common.

OROBANCHACEAE. BROOM-RAPE FAMILY

CONOPHOLIS. Squaw-root. Cancer-root

- C. americana* (L. f.) Wallr. Woods on White Creek, (Chandler); "Rock Point, Burlington," (Macrae); West Rutland, (H. M. Denslow); Snake Mountain, (Brainerd); Leicester, (Dutton); Townshend, (Wheeler).

EPIFAGUS. Beech-drops. Cancer-root

- E. virginiana* (L.) Bart. (*Leptamnium virginianum* [L.] Raf.). Beech-drops. Under beech trees; common.

OROBANCHE. (THALESIA). Broom-rape

- O. uniflora* L. One-flowered Cancer-root. Dry woodlands; occasional.

ACANTHACEAE. ACANTHUS FAMILY

DIANTHERA. Water Willow

- D. americana* L. Collected by Dr. Paddock, in 1819, in water at Ferrisburgh; specimen now in University of Vermont herbarium. No later botanist has found it in Vermont.

PHRYMACEAE. LOPSEED FAMILY

PHRYMA. Lopseed

- P. Leptostachya* L. Moist open woods of the lower altitudes; occasional.

PLANTAGINACEAE. PLANTAIN FAMILY

LITTORELLA

- L. uniflora* (L.) Asch. Gravelly shores; Kelley's Bay, Alburgh, (Pringle); Spectacle Pond, East Wallingford, (Kent); Notch Pond, Ferdinand, (Eggleston).

PLANTAGO. Plantain

- P. aristata* Michx. Occasionally introduced with grass seed.
*P. lanceolata** L. English Plantain, Rib Grass, Ripple Grass. Grass land; common.
P. major L. Common Plantain. Waysides; common.
P. Rugellii Dcne. Plantain. With the preceding species; common.

RUBIACEAE. MADDER FAMILY

CEPHALANTHUS. Buttonbush

- C. occidentalis* L. Swamps of the lower altitudes; frequent. North in the Connecticut Valley to Fairlee.

GALIUM. Bedstraw. Cleavers

- G. Aparine* L. Cleavers, Goose Grass. Shaded ground of the lower altitudes; frequent. In the Connecticut Valley north to Norwich.
G. asprellum Michx. Rough Bedstraw. Alluvial ground; common.
G. boreale L. Northern Bedstraw. Wet meadows; occasional.
G. lanceolatum Torr. Wild Liquorice. Dry woods of the lower altitudes; common.
G. Claytoni Michx. Wet meadows; frequent.
*G. erectum** Huds. Waste places; Charlotte, (Pringle); Bristol, (Dike); Westminster, (W. H. Blanchard).
G. kamschatcicum Steller. Cold wet woods of the higher mountains; frequent.
G. labradoricum Wiegand. Perch Pond bog, Pownal, (J. R. Churchill); Danby, (Mrs. N. F. Flynn).
G. lanceolatum Torr. Wild Liquorice. Dry woods of the lower altitudes; frequent.
*G. Mollugo** L. Wild Madder. "North Pomfret," (Morgan); Shelburne, (Mrs. N. F. Flynn); Bellows Falls, Putney and Dummerston, (W. H. Blanchard).
G. palustre L. Wet meadows and along ditches; common.
G. pilosum Ait. Dry copses; Pownal, (Robbins, Eggleston); West Haven, (G. H. Ross).
*G. sylvaticum** L. Scotch Mist, Baby's Breath. Established on shady ledge, Orwell, (Brainerd); Peacham, (Dr. F. Blanchard).
*G. sylvestre** Pollick. Charlotte, (Pringle).
G. tinctorium L. Wet meadows; frequent.
G. trifidum L. Cold bogs and marshy borders of ponds; frequent.
G. triflorum Michx. Sweet-scented Bedstraw. Rich woodlands; common.
*G. verum** L. Yellow Bedstraw. Occasionally introduced in grass lands.

HOUSTONIA

- H. caerulea* L. Bluets, Innocence. Grassy places and wet rocks; common.

H. longifolia Gaertn. Dry rocky places; frequent in the Champlain Valley. Randolph, (Bates).

MITCHELLA. Partridge Berry

M. repens L. Cool woods; common.

SHERARDIA. Field Madder

S. arvensis* L. Middlebury, (Brainerd).

CAPRIFOLIACEAE. HONEYSUCKLE FAMILY

DIERVILLA. Bush Honeysuckle

D. Lonicera Mill. (*D. Diervilla* [L.] MacM.). Rocky woodlands; common.

LINNAEA. Twin-flower

L. borealis L., var. **americana** (Forbes) Rehder. (*L. americana* Forbes). Cool rich woods; frequent.

LONICERA. Honeysuckle

L. caerulea L., var. **villosa** (Michx.) T. & G. Mountain Fly Honeysuckle. Cold bogs of northeastern Vermont; occasional. Norwich, (Jesup).

L. canadensis Marsh. American Fly Honeysuckle. Moist woods; common.

L. dioica L. Wild Honeysuckle. Dry rocky woods and sandy soil of the lower altitudes; frequent.

L. hirsuta Eat. Hairy Honeysuckle. Rocky woodlands of western Vermont; occasional.

L. oblongifolia (Goldie) Hook. Swamp Fly Honeysuckle. Cold bogs; occasional.

L. sempervirens L. Trumpet Honeysuckle. Townshend and Brattleboro, (Wheeler).

L. tatarica* L. Tartarian Honeysuckle. A frequent escape from cultivation.

SAMBUCUS. Elder

S. canadensis L. Common Elderberry. Thickets; common.

S. racemosa L. Red-berried Elder. Rocky woodlands; common.

SYMPHORICARPOS. Snowberry

S. racemosus Michx. Snowberry. Cliffs and headlands of western Vermont; occasional.

S. racemosus Michx., var. **laevigatus** Fernald. (*S. Symphoricarpos* [L.] MacM.). Garden Snowberry. Roadside escape.

TRIOSTEUM. Horse Gentian

T. aurantiacum Bicknell. Feverwort, Horse Gentian. Rich woodlands of the lower altitudes; occasional. North in the Connecticut Valley to Norwich.

VIBURNUM. Arrow-wood

- V. acerifolium** L. Maple-leaved Viburnum, Dockmackie. Dry rocky and sandy woods of the lower altitudes; common.
- V. alnifolium** Marsh. Hobblebush, Witch Hobble, Moosewood. Cold moist woods; common.
- V. cassinoides** L. Withe-rod, Wild Raisin. Swamps; common.
- V. dentatum** L. Arrow-wood. Wet places; frequent.
- V. Lentago** L. Sheepberry, Nannyberry, Sweet Viburnum. Rich moist woods and banks of the lower altitudes; frequent.
- V. Opulus** L., var. **americanum** (Mill.) Alt. Cranberry-tree, High-bush Cranberry, Pimbina. Low ground; frequent.
- V. pauciflorum** Raf. Squashberry, Pimbina. Moist ravines near limit of tree growth; Mt. Mansfield, (Tuckerman and Macrae); Killington Mt., (Sargent and Eggleston); Stratton Mt., (Underwood).
- V. pubescens** (Alt.) Pursh. Downy Arrow-wood. Common on the cliffs and rocky hills of the Champlain Valley.

VALERIANACEAE. VALERIAN FAMILY

VALERIANA. Valerian

- V. officinalis*** L. Garden Heliotrope. Garden escape, Franklin, (Wild); Burlington and Shelburne, (Mrs. N. F. Flynn).
- V. uliginosa** (T. & G.) Rydb. Cedar Swamp, Fairhaven, (Robbins, Seeley); Craftsbury, (Robbins).

DIPSACACEAE. TEASEL FAMILY

DIPSACUS. Teasel

- D. sylvestris*** Huds. Wild Teasel. Roadside weed; "Castleton," (Reed); Shoreham, (Brainerd); Charlotte, (Pringle).

KNAUTIA. (SCABIOSA)

- K. arvensis*** (L.) T. Coulter. Scabious. Charlotte, (Pringle).

CUCURBITACEAE. GOURD FAMILY

ECHINOCYSTIS. (MICRAMPELIS). Wild Balsam-apple

- E. lobata** (Michx.) T. & G. Wild Cucumber. Alluvial banks and waste places; frequent.

SICYOS. One-seeded Bur Cucumber

- S. angulatus** L. Star Cucumber. River banks and waste places; frequent.

CAMPANULACEAE. BLUEBELL FAMILY

CAMPANULA. Bellflower

- C. aparinoides** Pursh. Marsh Bellflower. Low sedgy thickets of the lower altitudes; occasional.

- C. glomerata** L. Clustered Bellflower. Chittenden, (Mrs. Emily H. Terry).
*C. rapunculoides** L. Bellflower. Roadside escape; occasional.
C. retundifolia L. Harebell, Bluebell. Rocky banks; common.
*C. Trachelium** L. Nettle-leaved Bellflower, Throatwort. Colchester, (Griffin).
C. uliginosa Rydberg. Low sedgy thickets of the lower altitudes; frequent.

SPECULARIA. (LEGOUZIA). Venus's Looking-glass

- S. perfoliata* (L.) A. DC. Dry rocky woodlands of the lower altitudes; occasional and local. Royalton, (Ward); Westminster, (W. H. Blanchard); South Burlington, (Mrs. N. F. Flynn).

LOBELIACEAE. LOBELIA FAMILY

LOBELIA

- L. cardinalis* L. Cardinal-flower. Swales and margins of ponds and streams; frequent. North in the Connecticut Valley to Hartland.
L. Dortmanna L. Water Lobelia. Shallow margins of ponds and bogs; occasional.
L. inflata L. Indian Tobacco. Fields and pastures; common.
L. Kalmii L. Cool moist rocks and fields; occasional
L. spicata Lam. Fields and waysides of the lower altitudes; occasional.

COMPOSITAE. COMPOSITE FAMILY

ACHILLEA. Yarrow

- A. Millefolium* L. Common Yarrow, Milfoil. Dry fields and roadsides; common.
A. Ptarmica L. Sneezeweed. Hartland, (Underwood).

AMBROSIA. Ragweed

- A. artemisiifolia* L. (*A. elatior* L.). Roman Wormwood, Hogweed, Bitter-weed. Waste places; common.
A. psilostachya DC. Introduced with western seed; Brandon, (Dutton); railroad yard, Burlington, (Mrs. N. F. Flynn).
A. trifida L. Great Ragweed. Moist alluvial soil; occasional. Var. *integrifolia* (Muhl.) T. & G. Burlington, (Mrs. N. F. Flynn).

ANAPHALIS. Everlasting

- A. margaritacea* (L.) B. & H. Pearly Everlasting. Dry hills and woods; common.

ANTENNARIA. Everlasting. Ladies' Tobacco

- A. Brainerdii* Fernald. Moist banks, usually in shade; occasional in the lower altitudes of central Vermont.

- A. canadensis** Greene. Dry and moist ground; common.
- A. fallax** Greene. In partial shade; occasional.
- A. neglecta** Greene. Indian Tobacco. Old fields; common.
- A. neodiola** Greene. Old pastures and fields; frequent.
- A. neodiola** Greene, var. **grandis** Fernald. Usually in shade; frequent.
- A. occidentalis** Greene. Meadows and hillsides; common in Addison County; Colchester, (Blake).
- A. Parlinii** Fernald. Dry banks and thickets of the lower altitudes; occasional.
- A. petaloidea** Fernald. Old pastures; common.
- A. plantaginifolia** (L.) Richards. Plantain-leaved Everlasting. Dry open woodlands of the lower altitudes; occasional.

ANTHEMIS. Chamomile

- A. arvensis*** L. Corn Chamomile. Westminster, Townshend, (W. H. Blanchard).
- A. Cotula*** L. Mayweed, Dog Fennel. Waste places; common.
- A. thectoria*** L. Yellow Chamomile. Townshend, (W. H. Blanchard).

ARCTIUM. Burdock

- A. Lappa*** L. Great Burdock. Waste places; frequent, especially in mountain towns.
- A. Lappa** L., var. **purpurascens*** (Le Grand) Fernald. Rhod. 12: 45. Cornwall, (Brainerd).
- A. minus*** (Hill) Bernh. Common Burdock. Waste places; common.

ARTEMISIA. Wormwood

- A. Abrotanum*** L. Southernwood. Garden escape; Willoughby Lake, (Kennedy).
- A. Absinthium*** L. Wormwood. Dry hills and roadsides; occasional. Rare in the Connecticut Valley.
- A. blennis** Willd. Introduced along railways; occasional.
- A. canadensis** Michx. Willoughby Lake, (A. Wood); Smugglers' Notch, Mt. Mansfield, (Pringle); slaty shore of northern Lake Champlain, (Brainerd).
- A. caudata** Michx. Sandy shores of Lake Champlain; occasional.
- A. ludoviciana** Nutt. (A. gnaphalodes Nutt.). Western Mugwort, White Sage. Along railroad, Bellows Falls, (W. H. Blanchard).
- A. pontica*** L. Garden escape; Westmore, (Kennedy).
- A. Stelleriana*** Bess. Beach Wormwood, Dusty Miller. Occasional as a garden escape.
- A. vulgaris*** L. Common Mugwort. Waste places; common.

ASTER. Aster

- A. acuminatus** Michx. Cool rich woods; common.
- A. amethystinus** Nutt. Moist ground. "Brattleboro," (Frost); South Pownal, (Eggleston).

- A. cordifolius* L. Woodlands; common. Var. *Furbishiae* Fernald. Banks of streams; occasional. Var. *polycephalus* Porter. Johnson, (Grout).
- A. divaricatus* L. Moist woodlands; common.
- A. ericoides* L. Dry open places of the lower altitudes of southern Vermont; occasional. Var. *Pringlei* Gray. (A. *Pringlei* Britton). Slaty headlands and islands of Lake Champlain; frequent. Manchester, (Mary A. Day).
- A. junceus* Ait. Peat bogs; rare.
- A. laevis* L. Borders of woodlands of the lower altitudes of southern Vermont; frequent.
- A. lateriflorus* (L.) Britton. Thickets and fields; common.
- A. lateriflorus* (L.) Britton, var. *hirsuticaulis* (Lindl.) Porter. (A. *hirsuticaulis* Lindl.). Borders of thickets. "Bellows Falls," (Carey); Burlington, (Macrae, Mrs. N. F. Flynn); Highgate Springs, (Jesup); Brattleboro, (Grout).
- A. linariifolius* L. (*Ionactis linariifolius* Greene). Sandy soil of the lower altitudes; occasional.
- A. Lindleyanus* T. & G., var. *comatus* Fernald. Ripton, Bellows Falls, (W. H. Blanchard).
- A. longifolius* Lam. North Pownal, (Eggleston); Connecticut Valley, (W. H. Blanchard); Willoughby Lake, (Kennedy); Jamaica, (Wheeler). Var. *villicaulis* Gray. Connecticut Valley (W. H. Blanchard); West Concord, (Eggleston).
- A. macrophyllus* L. Moist woods; common. Var. *excelsior* Burgess. Frequent. Var. *pinguifolius* Burgess. Occasional. Var. *sejunctus* Burgess. Frequent. Var. *velutinus* Burgess. St. Johnsbury, (Inez A. Howe).
- A. multiflorus* Ait. Dry hilly pastures. Pownal, (Robbins, Eggleston); Vernon, (Grout). Var. *exiguus* Fernald. In railroad yard, Norwich, (H. E. Sargent).
- A. nemoralis* Ait. Rocky shores of North Pond, Brunswick, (Eggleston).
- A. nemoralis* Ait., var. *Blakel* Porter. Belden Pond, Johnson, (Grout).
- A. novae-angliae* L. New England Aster. Moist ground; common in western Vermont from Addison County southward; less so elsewhere. Var. *roseus* (Desf.) DC. Occasional.
- A. novi-belgii* L. Moist shady soil, Connecticut Valley; occasional.
- A. paniculatus* Lam. Shady moist soil; common. Var. *acutidens* Burgess. Westminster, (W. H. Blanchard). Var. *bellidifolius* (Willd.) Burgess. Rutland, (Eggleston); Willoughby Lake, (Kennedy). Var. *cinerascens* Fernald. Westminster, (W. H. Blanchard). Var. *lanatus* Fernald. Willoughby Lake, (E. F. Williams). Var. *simplex* (Willd.) Burgess. Westminster, (W. H. Blanchard); Rutland, (Kirk).
- A. polyphyllus* Willd. (A. *Faxonii* Porter). Willoughby Mountain, (Tuckerman, Faxon); "A dwarf form in pastures, Newark and Sutton," (E. Faxon); St. Johnsbury, (Inez A. Howe).

- A. prenanthoides* Muhl. Newfane, (Grout); Taftsville, (Nancy Darling).
- A. ptarmicoides* T. & G. Dry limestone ledges, Bennington County; occasional. West River, Jamaica; rare; (W. H. Blanchard).
- A. puniceus* L. Red-stalked Aster. Low thickets and swamps; common. Var. *demissus* Lindl. Occasional. Var. *firmus* (Nees) T. & G. Sudbury, (F. W. Hubby); Mt. Killington, (Kirk). Var. *lucidulus* Gray. Brandon, (Dutton).
- A. radula* Ait. "Brattleboro," (Frost); Cranberry Pond bog, Ferdinand, (Eggleston).
- A. sagittifolius* Wedemeyer. Dry ground. Common in the Hoosic Valley, Pownal, (Eggleston). Only known station in New England.
- A. Schreberi* Nees. Common in southern Vermont.
- A. tardiflorus* L. Moist shady ground; occasional. Var. *vestitus* Fernald. Westminster, (W. H. Blanchard); Hartland, (Nancy Darling); Willoughby Lake, (Kennedy).
- A. Tradescanti* L. Low grounds; occasional.
- A. umbellatus* Mill. (*Doellingeria umbellata* [Mill.] Nees). Moist thickets; common.
- A. undulatus* L. Dry copses of the lower altitudes; common.
- A. vimineus* Lam. Moist banks; occasional. Var. *foliolosus* (Ait.) Gray. Ledges, Sumner's Falls, Hartland, (Eggleston).
- A. vimineus* Lam., var. *saxatilis* Fernald. (*A. saxatilis* [Fernald] Blanchard). Ledges, Winooski River, Williston, (Pringle); Connecticut River, Bellows Falls to Brattleboro, (W. H. Blanchard).

BIDENS. Bur Marigold

- B. Beckii* Torr. (*Megalodonta Beckii* [Torr.] Greene). Water Marigold. Ponds and deep slow streams; occasional.
- B. cernua* L. Stick-tight. Wet places; common.
- B. comosa* (Gray) Wiegand. Wet shores; rare.
- B. connata* Muhl. Swamp Beggar-ticks. Low margins of streams and lakes; frequent.
- B. discolor* (T. & G.) Britton. Maquam Bay, Swanton, (Blake).
- B. frondosa* L. Common Beggar-ticks. Moist waste places; common. Var. *anomala* Porter. Lake Bomoseen, (Kirk).
- B. vulgata* Greene. Beggar-ticks, Stick-tight. Waste ground; common.

CARDUUS. Plumeless Thistle

- C. crispus** L. Curled Thistle. South Burlington, (Chittenden).

CENTAUREA. Star Thistle

- C. Cyanus** L. Bluebottle, Bachelor's Button, Corn-flower. Occasionally adventive.
- C. Jacea** L. Meadow Centaury. Charlotte, (Pringle); Stowe, (Mrs. Carrie E. Straw).
- C. Jacea* L., var. *lacera** Koch. Berkshire, (Mrs. Frances Jolley).

CHRYSANTHEMUM. Ox-Eye Daisy

- C. Leucanthemum* L., var. *pinnatifidum** Lecoq and Lamotte. Fields and meadows; common.

CICHORIUM. Succory or Chicory

- C. Intybus** L. Common Chicory, Blue Sailors. Roadsides and meadows; more common in western Vermont.

CIRSIIUM. Common or Plumed Thistle

- C. arvense** (L.) Scop. Canada Thistle. Fields and waste places; common.
*C. canum** (L.) Bleb. Castleton, (A. E. Higley).
C. discolor (Muhl.) Spreng. Field Thistle. Copses of the lower altitudes of southern Vermont; occasional.
*C. lanceolatum** (L.) Hill. Common or Bull Thistle. Pastures and roadsides; common.
C. muticum Michx. Swamp Thistle. Swamps and low woods; frequent.
C. pumilum (Nutt.) Spreng. (*C. odoratum* [Muhl.] Britton). Pasture or Bull Thistle. The most common pasture thistle of the southern counties of western Vermont; unknown north of Rutland County.

CREPIS. Hawk's Beard

- C. biennis** L. Charlotte, (Pringle).
*C. capillaris** (L.) Wallr. (*C. virens* L.). Townshend, (W. H. Blanchard); Stowe, (Mrs. Carrie E. Straw).
*C. setosa** Haller. Townshend, (W. H. Blanchard).

DYSSODIA. (BOEBERA). Fetid Marigold

- D. papposa* (Vent.) Hitchc. Adventive on wool waste, bank of Winooski River, Burlington, (Brainerd).

ERECTHITES. Fireweed

- E. hieracifolia* (L.) Raf. Moist woods, especially in recent clearings; common.

ERIGERON. Fleabane

- E. annuus* (L.) Pers. Daisy Fleabane, Sweet Scabious. Fields and waste places; common.
E. canadensis L. (*Leptilon canadense* [L.] Britton). Horse-weed, Butter-weed. Waste places; common.
E. hyssopifolius Michx. Moist rocky river banks and mountain cliffs; occasional.
E. philadelphicus L. Daisy Fleabane. Moist ground; common.
E. pulchellus Michx. Robin's Plantain. Copses and moist banks; common.
E. ramosus (Walt.) BSP. Daisy Fleabane. Fields; common.

EUPATORIUM. Thoroughwort

- E. perfoliatum** L. Boneset, Thoroughwort. Low grounds; common.
 Var. **truncatum** Gray. Hartland, (Underwood); Colchester, (Blake).
E. purpureum L. Joe-Pye Weed, Trumpet Weed. Essex Junction, North Ferrisburgh, (Blake); Highgate, (Blewitt).
E. purpureum L., var. **amoenum** (Pursh.) Gray. Dry open woods, Pownal, (Eggleston).
E. purpureum L., var. **foliosum** Fernald. Essex Junction, (Blake).
E. purpureum L., var. **maculatum** (L.) Darl. (*E. maculatum* L.). Joe-Pye Weed, Trumpet Weed. Moist thickets and low grounds; common.
E. sessilifolium L. Upland Boneset. Dry open woods about base of cliff, North Pownal, (Eggleston).
E. urticaefolium Reichard. White Snakeroot. Moist rich woods; common.

GALINSOGA

- G. parviflora** Cav., var. **hispida*** DC. Becoming common as a garden weed.

GNAPHALIUM. Cudweed

- G. decurrens** Ives. Everlasting. Hillsides; common.
G. polycephalum Michx. (*G. obtusifolium* L.?). Common Everlasting. Old fields and woods; common.
G. uliginosum L. Low Cudweed. Moist soil; common.

HELIANTHUS. Sunflower

- H. annuus** L. Common Sunflower. An occasional escape.
H. decapetalus L. Wild Sunflower. Copses and low banks of streams; frequent.
H. divaricatus L. Thickets and barrens of the lower altitudes; frequent.
H. giganteus L. "Brattleboro," (Frost); Randolph, (Bates); "Royalton," (Ward).
H. petiolaris Nutt. Adventive, Burlington, (Helyer); St. Johnsbury, (Inez A. Howe).
H. strumosus L. Dry woods and banks of the lower altitudes of western Vermont; occasional.
H. tuberosus L. Jerusalem Artichoke. Along fences and roadsides; frequent.

HELIOPSIS. Ox-Eye

- H. helianthoides** (L.) Sweet. North Pownal, (Woodward); Lyndon, (Inez A. Howe).
H. scabra Dunal. Franklin, (Wild); Hartford and Norwich, (H. E. Sargent); Burlington, (Jones); Shelburne, (Mrs. Gebhardt).

HIERACIUM. Hawkweed

- H. aurantiacum** L. Orange Hawkweed, Devil's Paint-brush, Grim the Collier. Common. A weed pest in pastures and lawns, especially in the northwestern counties.
- H. canadense* Michx. Dry cool woods; frequent.
- H. florentinum** All. King Devil. Burlington, (Mrs. N. F. Flynn); Colchester, (Griffin); Rutland and Sherburne, (Kirk).
- H. floribundum** Wimm. & Grab. Franklin, (Underwood); Brattleboro, (Wheeler).
- H. marianum* Willd. Bellows Falls, (W. H. Blanchard).
- H. paniculatum* L. Open woods; frequent.
- H. pilosella** L. Mouse-ear. Grassland; rare.
- H. praealtum* Gochnat, var. *decipiens** Koch. South Burlington, (Mrs. Jane Walker).
- H. pratense** Tausch. King Devil. Berkshire, (Mrs. Frances Jolley).
- H. scabrum* Michx. Dry open woods; common.
- H. venosum* L. Rattlesnake-weed, Poor Robin's Plantain. Dry plains and pine woods of the lower altitudes; occasional.
- H. vulgatum** Fries. Common in woods near Evergreen Cemetery, Rutland, (Kirk).

INULA. Elecampane

- I. Helenium** L. Elecampane. Roadsides and damp pastures; frequent.

IVA. Marsh Elder. Highwater Shrub

- I. xanthifolia* Nutt. Adventive. Manchester, (Mrs. Mary C. Munson); Stowe, (Mrs. Carrie E. Straw).

KRIGIA. (CYNTHIA). Dwarf Dandelion

- K. virginica* (L.) Willd. Dry sterile soil of the Connecticut Valley; occasional.

LACTUCA. Lettuce

- L. canadensis* L. Wild Lettuce, Horse-weed. Rich damp soil, borders of fields and thickets; common. Var. *montana* Britton. Burlington, (Mrs. N. F. Flynn).
- L. hirsuta* Muhl. Charlotte, (Pringle).
- L. integrifolia* Bigel. (*L. sagittifolia* Ell.). Newfane, (Grout); Pownal, (Eggleston); Middlebury, (Brainerd).
- L. scariola* L., var. *integrata** Gren. & Godr. (*L. virosa* L.). Prickly Lettuce. Waste places; spreading rapidly.
- L. spicata* (Lam.) Hitchc. Wild Blue Lettuce. Low ground; common.

LAPSANA. (LAMPSANA). Nipplewort

- L. communis** L. Brattleboro, (Frost); Ferrisburgh and Rutland, (Kirk); Townshend, (W. H. Blanchard).

LEONTODON. (APARGIA). Hawkbit

*L. autumnalis** L. Fall Dandelion. Abundant on village green, Irasburgh, (Hazen); Rutland, (Kirk).

MATRICARIA. Wild Chamomile

*M. suaveolens** (Pursh.) Buchenau. (*M. matricarioides* [Less.] Porter). Pineapple-weed. Adventive from Pacific coast. Abundant along railroads and highways in many places.

ONOPORDUM. Cotton or Scotch Thistle

*O. Acanthium** L. Cotton Thistle. "Dry pastures, Williston and Grand Isle," (Robbins); Charlotte, (Pringle); Williston, (Mrs. N. F. Flynn).

PETASITES. Sweet Coltsfoot

P. palmatus (Alt.) Gray. Wooded borders of cold swamps and streams; occasional.

PICRIS

*P. echioides** L. Ox-tongue. Hartland, (Webster).

*P. hieracioides** L. Charlotte, (Pringle).

POLYMNIA. Leafcup

P. canadensis L. Limestone ledges, Rutland and Proctor, (Eggleston).

PRENANTHES. (NABALUS). Rattlesnake-Root

P. alba L. White Lettuce, Rattlesnake-root. Borders of rich woods of the lower altitudes of western Vermont; occasional. Vernon, (Grout); West River, (Wheeler).

P. altissima L. Gall-of-the-earth. Rich moist woods; common. Var. *hispidula* Fernald. Monkton, (Pringle).

P. Bootii (DC.) Gray. Mansfield Chin and Nose, (Pringle).

P. nana (Bigel.) Torr. Top of Willoughby Mt., (Rusby).

P. racemosa Michx. Along railroad, Swanton, (Blake).

P. trifoliata (Cass.) Fernald. Gall-of-the-earth. Dry sterile soil; frequent.

RUDBECKIA. Cone-flower

R. hirta L. Yellow Daisy, Black-eyed Susan, Nigger-head. Meadows; common.

R. laciniata L. Tall Cone-flower, Thimble-weed. Low thickets; frequent.

SENECIO. Groundsel. Ragwort. Squaw-weed

S. aureus L. Golden Ragwort. Swamps; common.

S. Balsamitae Muhl. (*S. pauperculus* Michx.). Moist cliffs and rocky banks of streams; frequent.

S. Balsamitae Muhl., var. *praelongus* Greenman. Manchester, (Mary A. Day); Essex, (F. A. Ross); Burlington, (Jones).

- S. obovatus* Muhl. Dry open woods; Bennington and Pownal, common, (Robbins, Churchill); Essex, (F. A. Ross); Townshend, (Wheeler).
S. Robbinsii Oakes. Common in the cold swamps of northern and central Vermont. Summit of Ascutney Mt. and Windham, (W. H. Blanchard); Hartland, (Nancy Darling); Rutland, (Eggleston).
*S. vulgaris** L. Common Groundsel. Garden weed; occasional.

SERICOCARPUS. White-topped Aster

- S. asteroides* (L.) BSP. Dry open woods. Pownal and Arlington, (Robbins); Vernon, (Grout); Brattleboro, (W. H. Blanchard).

SILPHIUM. Rosin-weed

- S. perfoliatum* L. Cup Plant. Burlington, (Jones); Westminster, (W. H. Blanchard).

SOLIDAGO. Golden-rod

- S. altissima* L. (*S. canadensis*, Gray's Manual, ed. 6 in part). Copses of the lower altitudes; occasional.
S. altissima L., var. *procera* (Alt.) Fernald. Manchester, (Mary A. Day).
S. arguta Ait. Copses and moist woods of the lower altitudes; common.
S. bicolor L. White Golden-rod. Dry copses; common.
S. caesia L. Rich woodlands of the lower altitudes; common. Var. *axillaris* (Pursh) Gray. Burnt over woodlands; common. Var. *paniculata* Gray. Rich woods; occasional.
S. canadensis L. (*S. canadensis* L., var. *glabrata* Porter). Borders of thickets and fields; common.
S. canadensis L., var. *gillivocanescens* Rydb. St. Johnsbury, (Inez A. Howe).
S. Cutleri Fernald. (*S. Virgaurea*, var. *alpina* Bigel.). Mt. Mansfield and Camel's Hump, (Brainerd); Mt. Horrid, (Dutton); Lunenburg, (W. E. Balch).
S. graminifolia (L.) Salisb. (*Euthamia graminifolia* [L.] Nutt.). Moist soil; common.
S. hispida Muhl. Dry sterile soil; occasional. More abundant in northern Vermont.
S. juncea Ait. Copses and banks of the lower altitudes; common. Var. *scabrella* (T. & G.) Gray. More rocky situations than type; common.
S. latifolia L. (*S. flexicaulis* L. in part). Moist shaded banks; frequent.
S. macrophylla Pursh. Highest peaks of the Green Mountains; common above 3,000 feet.
S. neglecta T. & G. Bogs and swamps of the lower altitudes; occasional.
S. nemoralis Ait. Dry sterile fields; common.
S. odora Ait. Sweet Goldenrod. "Woods," (Oakes); Vernon, rare, (W. H. Blanchard).

- S. patula* Muhl. Swamps; frequent in Bennington and Rutland Counties.
- S. puberula* Nutt. Sandy soil of the lower altitudes; occasional.
- S. racemosa* Greene. (*S. humilis* Gray's Manual, ed. 6 in part, not Pursh). Rock banks of lakes and streams; occasional.
- S. Randii* (Porter) Britton. (*S. Virgaurea* and var. *Redfieldii* Porter). Shady cliffs of the quartzite range of the Green Mountains, at an altitude of 1,000-2,000 feet; cliffs of Mt. Mansfield and Willoughby Mountain; headlands of Lake Champlain; common. Var. *monticola* (Porter) Fernald. Cliffs, Mt. Mansfield and Willoughby Mt.; common.
- S. rugosa* Mill. Borders of fields and copses; common.
- S. serotina* Ait. Copses and fencerows of the lower altitudes; common.
- S. serotina* Ait., var. *gigantea* (Ait.) Gray. Low grounds and moist thickets; frequent.
- S. squarrosa* Muhl. Rocky woods; occasional.
- S. uliginosa* Nutt. Peat bogs; occasional.
- S. ulmifolia* Muhl. About base of the cliffs, North Pownal, (Eggleston); Hartland, (F. P. Whiting).
- S. macrophylla* x *rugosa* Fernald. Near summit of Mt. Killington, (Dutton and Kirk).

SONCHUS. Sow Thistle

- S. arvensis** L. Field Sow Thistle. Shores and waste places, becoming frequent.
- S. asper** (L.) Hill. Spiny-leaved Sow Thistle. Waste places in rich soil; frequent.
- S. oleraceus** L. Common Sow Thistle. Waste places with the preceding.

TANACETUM. Tansy

- T. vulgare** L. Common Tansy. Roadsides; frequent. Var. *crispum** DC. With the species; frequent.

TARAXACUM. (LEONTODON). Dandelion

- T. erythrospermum** Andr. Red-seeded Dandelion. Shallow soil about ledges; frequent.
- T. officinale** Weber. (*L. Taraxacum* L.). Common Dandelion. Common. Var. *palustre** (Sm.) Blytt. Rutland, (Eggleston).

TRAGOPOGON. Goat's Beard

- T. pratensis** L. Waste places; frequent.

TUSSILAGO. Coltsfoot

- T. Farfara** L. Moist clay banks and along mountain streams; common.

XANTHIUM. Cocklebur

- X. canadense* Mill. (*X. americanum* Walt.). Shores of lakes and rivers; frequent.
- X. commune* Britton. Shores of Lake Champlain; common.
- X. echinatum* Murr. Lake shores and river banks; common.

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BURLINGTON, VT.

BULLETIN No. 188

APRIL, 1915

Forest Planting in Vermont as an Investment

BURLINGTON:
FREE PRESS PRINTING COMPANY,
1915

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Plantation of White Pine on the Chas. Downer State Forest, Sharon, Vt.



Fifteen-year-old plantation of White Pine made by Prof. L. R. Jones in South Burlington, Vt.



Plantation of Scotch Pine, five years old, Sharon, Vt.



Plantation of Scotch and White Pine on bare sand, Lyndon State Forest, two years after planting.

BULLETIN 188 FOREST PLANTING IN VERMONT AS AN INVESTMENT

By A. F. HAWES, STATE FORESTER

VERMONT FORESTRY PUBLICATION No. 17

SUGGESTIONS FOR THE PROSPECTIVE FOREST PLANTER

1. A forest needs no fertilizer and very little care.
2. Taxation on forest plantations in Vermont is limited by law.
3. Only a rich man can afford to own unproductive land.
4. One acre of planted pine will produce a car load of lumber in 35 years.
5. A manufacturer can grow pine lumber for much less than he can buy it by the time it is grown.
6. A good growing forest often helps to sell the farm.
7. You can take a look at your forest plantation every Sunday, but you wouldn't know much about Wall Street if you camped there all summer.
8. If in doubt about planting, ask someone in your neighborhood who has tried it. The State Forest Service will send a complete list of Vermonters who have planted its trees.
9. The proceeds from one acre of pine plantation 45 years old would support a one-room school a year. If a town planted 45 acres, taxes for one school could eventually be eliminated.
10. In 1914 the State of Vermont spent about \$370,000 for highway improvement. If the state owned ready to cut 1,250 acres of 40-year old pine plantation, the income would be sufficient to meet this expenditure. With 50,000 acres planted to forests 1 to 40 years old, taxation for state highway purposes at the present rate could be eliminated.

LAND WHICH SHOULD BE REFORESTED IN VERMONT

The United States Census shows that the total area of forest and waste land in Vermont is 3,719,000 acres, or 64 percent of her total area. It is impossible to say how much of this is covered with growing timber and how much is non-productive.

Abandoned pasture. Much land formerly used for farm purposes has been allowed to revert to a wild condition during the past generation. While some of this land can be reclaimed for agriculture, the expense is so great that only the best land is worth reclaiming. Much is seeding up naturally with tree growth, but this process is slow and often non-economic because many poor species gain entrance, and because even the good species are too widely spaced to make good timber. It is not so much a question whether the owners of this class of land can afford to reforest it, as whether they can afford to pay taxes on unproductive land for a long term of years. Many Vermonters would be better off if they gave away the unproductive part of their lands. The new tax law, described on page 294, offers an incentive to reforest this class of land.

Cut-over woodland. Thousands of acres of land formerly covered with timber, but which have been cut-over during the past quarter of a century, are coming up with a more or less worthless growth of trees and brush. Where fire followed lumbering, such land is often not worth paying taxes on. Even where it escaped fire it has been shown¹ that the growth of hardwoods which usually follows is a much less profitable investment to hold than the same land would be planted to pine. In other words, the profits from planting are enough greater than those from natural hardwood growth to make planting of this cut-over land a good investment, provided it can be protected from fire.

Openings in the forest. In most of our woodlots and forests there are non-productive openings which seriously deplete the profit from the timber. These should be reforested artificially if they are not seeding in with the valuable species.

Total area to be planted. Altogether it is safe to say that at least 20,000 acres should be annually reforested in Vermont for the next 40 years. This would call for an annual planting of about 24 million trees, as compared with less than a million now planted annually.

¹Vt. Sta. Bul. 176, (1914), Vt. For. Serv. Pub. 13.

Planting during the last few years. The state forest nursery was established by an act of the Legislature of 1906, and forest planting started on a small scale in 1908; but no extensive planting was done until the establishment of the State Forest Service in 1909. During the past 6 years the planting in Vermont has been as follows:

1909 and 1910	572,200 trees
1911 and 1912	1,010,700 trees
1913 and 1914	1,497,650 trees

3,080,550 trees

While the chief value of these plantings is educational in directing land owners' attention toward other lines of forestry and bringing about more extensive planting, it represents a total area of about 3,000 acres planted. This in itself seems small compared to the total area in the State which should be planted. If plantations were no more productive than natural forests, the actual results in lumber would be insignificant. But as every one realizes that a cultivated potato patch will produce more than one left to itself, so it must be remembered that a forest plantation is much more productive than a forest which has seeded up of itself. A pine plantation 40 years old will produce an average of 25,000 feet per acre, and one 50 years old will produce 37,000 feet per acre. The area already planted, therefore, may be expected to yield by 1954 about 75,000,000 feet, or by 1964 about 111,000,000 feet. At \$10 per thousand feet, this means a stumpage value of \$750,000 and \$1,110,000 respectively. Allowing 17,000 feet of lumber as the average load of a freight car, the lumber produced from these plantations would fill a freight train of 4,400 cars. If it were all shipped to New York and Boston it would bring to the railroads in freight rates about \$200,000; whereas, if it were all used in Vermont it would have an employment value from the stump to the finished product of from \$2,500,000 to \$6,000,000 according to its uses.

Success of plantations. Most of the forest plantations set out in Vermont during the past few years have been successful and have given satisfaction to their owners. In the great majority of cases fully 80 percent of the trees planted have lived through the first year; in many cases over 95 percent. In practically all cases where less than 70 percent have taken root "there's a reason." In a few of these the trees have not been delivered promptly, either through fault of the express companies or neglect of the purchaser

to send for them. In several cases the trees have been carelessly planted. One man distributed trees every six feet on the ground and several hours later sent a crew to plant them, an exposure which of course, was fatal. In a few cases plantations have been damaged by fire or grazing. After all, the best indication that the plantations have given satisfaction is the fact that many land owners have continued planting from year to year.

LIST OF OWNERS WHO HAVE PLANTED DURING 6 DIFFERENT YEARS

Name and address	Trees	Name and address	Trees
Charles Richardson, Brattleboro,	16,000	T. D. Hobart, Berlin,	43,000
Dr. Wm. S. Stevens, Enosburg,	213,000	J. J. Parker, Sharon,	6,100
P. J. Farrell, Swanton,	4,500	F. E. Spellman, Springfield,	16,500

LIST OF OWNERS WHO HAVE PLANTED 4 DIFFERENT YEARS

Name and address	Trees	Name and address	Trees
E. B. Barrows, Brattleboro,	9,000	Hon. O. L. Martin, Plainfield,	10,500
A. L. Powers, Woodstock,	40,500	Scott Farm, Dummerston,	57,000
B. H. Lamb, Sharon,	4,300	C. C. Putnam & Son, Middlesex,	32,500
Burt Bros., Stowe,	20,000		

LIST OF OWNERS WHO HAVE PLANTED 3 DIFFERENT YEARS

Name and address	Trees	Name and address	Trees
Hon. E. S. Brigham, St. Albans,	2,000	A. A. Priest, Randolph,	10,000
C. A. Ricker, Groton,	10,800	Holden & Martin, Brattleboro,	35,000
L. C. Croft, Clarendon,	5,000	Bridgewater Woolen Co., Wood-	
E. S. Stearns, Lincoln,	12,000	stock,	71,000
Hon. T. N. Vail, Lyndon,	26,000	A. B. Morgan, Woodstock,	10,000
Newton and Thompson, Brandon,	41,700	Dr. W. L. Wasson, Waterbury,	10,000
Miss Mary Woodbury, Weathers-		J. O. Cannon, Rochester,	34,000
field,	25,200	W. D. Woolson, Springfield,	63,300
Miss C. Vaughan, Thetford,	5,000	Mrs. E. J. Sherman, Windsor,	5,000
Hon. D. T. Hanley, Milton,	14,500	A. B. Finney, Sharon,	3,500
E. L. Bass, Bethel,	2,200	City of Montpelier, Berlin,	75,000

Of the earlier state plantations, those made at Sharon in 1910 are the most satisfactory. Plantations of three-year white pine transplants made the same season in the same way on this and the Plainfield forest, show great variation in results. About 95 percent of the trees on the Charles Downer state forest at Sharon, and about 65 percent of the trees on the L. R. Jones state forest at Plainfield, were alive in 1914. The chief factor which caused the relatively unfavorable outcome at Plainfield was apparently the strong grass growth, causing excessive transpiration of moisture and damage by grubs. Greater care should have been used on this site in removing the sod at the time of planting.

Of the three species of pine planted in 1910 at Sharon, the white and Scotch pine have thus far grown considerably better than the Norway pine. On this light loam soil the white pine has grown even better than the Scotch pine, a great many trees having increased over thirty inches during the past year. This experience is unlike that secured in the state plantations at Lyndon, and on forest lands owned by the University of Vermont in Burlington and South Burlington. In these

locations, which are on sandy soils, the Scotch pine has considerably outgrown the white pine planted beside it.

Plantations of Norway spruce made on upland pastures at Sharon and elsewhere in grass, have not been very successful; while those made by Dr. Wm. S. Stevens, and Mr. T. D. Hobart and others, on moist land where there were more ferns than grass, have met with very good success.

SAFETY OF AN INVESTMENT IN FOREST PLANTING

Two things must be considered in regard to any investment: probable profit and safety.

It is often suggested that substitutes will be introduced for lumber, and it is probably true that the maximum prices which lumber will command, in the future, will be regulated by competition with other materials. It can be said, however, that with all the recent substitutes introduced the utilization of lumber and wood has increased in United States even more rapidly than the population. While it is likely that substitutes will take the place of lumber for certain purposes, it is very doubtful whether a sufficient variety will ever be invented to reduce materially the many demands made upon a lumber like white pine, which is used for so many purposes.

It is also claimed by some that so many men plant pine that there is likely to be an overproduction of this kind of lumber, as compared with hardwoods. The numerous uses of softwood, especially pine, will probably always make the demand for this wood exceed that for hardwoods, as it does at present. There will be, for a great many years, more land mismanaged, which will naturally reproduce with hardwoods, than well managed: and the amount of pine raised in all the plantations made will be insignificant for a great many years, as compared with the demand, as is readily seen from the fact that the country uses annually 3,138,227,000 board feet of white pine, and in all 30,526,416,000 feet of softwood lumber, or 78 percent of the total production.

The chief danger to an investment in forest planting is, of course, through forest fire. In this regard Vermont offers the best opportunities for safe investment of any of the eastern states, since her fire risk is less. During the six years, 1909 to 1914, inclusive, the total area burned in Vermont was 16,346 acres, an average of 2,725 acres a year. This area annually burned over is 0.09 percent of the

wooded area of the state, as compared with 0.2 percent in New York, 0.24 percent in Maine, 1.5 percent in Massachusetts and Rhode Island, and 2.3 percent in New Jersey. In other words at this rate it would require 1,111 years to burn over the wooded area of Vermont, as compared with 500 years in New York, 417 years in Maine, 66 years in Massachusetts and Rhode Island, and 44 years in New Jersey.

Forest fire risk in Vermont, with the present organization, is not sufficiently great to deter anyone from planting except in particularly dangerous situations. The only reason that it is considered a serious obstacle is that the bad fire years of 1903 and 1908, before the Forest Service was organized, are fresh in the minds of most people, and because they read of the serious fires in other states. It should be said in this connection, however, that the conditions favoring fires in some sections of Vermont are steadily growing worse because of the extensive slash made by large lumber operations, and it is only by maintaining an efficient fire service that the present low risk can be maintained.

There is no other serious risk in connection with forest planting. Much damage may be done by live stock in the first years of a plantation, but this is easily eliminated by fencing. In some localities damage may be done by deer. There have been a few instances of deer browsing on planted pine, especially the Scotch pine. As deer will not be allowed to multiply greatly this is hardly a serious risk.

Insects and fungi are likely to do some damage, but probably no greater, if as great, than in the case of agricultural crops. They should not deter anyone from planting, except in the case of some species which are particularly susceptible to such damage.

KIND OF TREES TO PLANT

In deciding upon species to be used in forest planting, the forester considers three points:

(a) Like the lumberman, he considers first the price which the different species may be expected to bring. Woods bring the highest prices which have some special quality which recommends them for special uses. The woods in Vermont which today bring the highest prices, are: white pine, because of its straight even grain, softness, and the ease with which it is worked; white ash, because of its bending qualities; basswood, because of its evenness of texture, freedom from defects, &c.; and oak, because of its strength and orna-

mental graining. Such woods as hemlock, fir and beech would not be recommended on this basis.

(b) The forester also considers a point not taken into account by the lumberman, viz.: the rate of growth. If one is engaged only in manufacturing lumber he naturally does not care how long it took the trees to grow; but if one is engaged in growing timber he is as much interested in the rate of growth as in the price at which the lumber will sell. In Vermont the native trees of most rapid growth are white and Norway pine, balsam fir and poplar. Trees whose slow growth discourage planting are the native spruce, hemlock, beech, birch and maple. A few foreign trees are recommended because of their rapid growth, such as the Norway spruce, European larch and Scotch pine.

(c) He considers in the third place the enemies which damage the different trees. White pine, for example, is recommended for the first two reasons, but is seriously damaged by the weevil,¹ pine blight and the blister rust disease. While Scotch and Norway pine are not specially valuable, they are much more apt to be free from disease. One of the chief objections to the planting of oak is the fact that its foliage is a favorite food of the gipsy moth, which is almost sure to gain entrance into Vermont within a few years. The black locust would otherwise be well worth planting were it not for the locust borer.

Taking these various factors into consideration, the following trees are especially recommended for planting in Vermont: white pine, red or Norway pine, Scotch pine, European larch, Norway spruce, white spruce, balsam fir, white ash.

THE WHITE PINE—*Pinus strobus*

The white pine has been the chief tree advocated for planting in New England, because it thrives on dry sandy soils, as well as on the better classes of soils, because it grows very rapidly, and because it makes a soft workable wood which is in great demand. This ability of the white pine to grow on practically all soils recommends it highly for general use, but it prospers best where the soil is fairly deep, moist and loamy. The heavy clay lands of Addison county originally bore extensive pine forests, as the old stump fences still demonstrate.

Its root system is not large and there is no well developed tap-

¹See p. 281: also Vt. Sta. Bul. 156, (1911), Vt. For. Serv. Pub. 4.

root. The large topped trees grown in the open have a more extensive root system than the small topped trees of a close stand.

The action of light on the chlorophyll of the leaves is necessary to enable the leaves or needles of a tree to absorb carbon dioxide from the air. The carbon thus obtained, combined with water taken in through the roots, is the chief element of wood. The growth of a tree depends, therefore, not only upon the fertility and moisture of the soil, but upon the amount of light available for the leaves. White pine requires more light than the spruce, hemlock and maple, but less than poplar, white birch, tamarack and red pine. The trees requiring least light also cast the heaviest shade. Pine seedlings will live for years under the moderate shade of poplar and birch, but will soon die under spruce and hemlock. The light shade during the first few years may be a benefit in case of very hot, dry weather, but should be removed in a clearing after the pines have become well established.¹

On the whole the white pine is the most rapid growing tree of New England. Although individual specimens of other species may grow as fast, acre for acre pine will produce more lumber than any other species. A height growth of three feet a year is sometimes found on young trees, and a diameter growth on older trees of one inch; however, these figures are above the average.²

The great demand for white pine is due to the softness of the wood which makes it easily worked. For some purposes, as in the manufacture of matches, small boxes, &c., where short pieces can be used, the white pine is unequalled because of the fact that its branches grow in whorls and knots can therefore be discarded with very little loss. The greater the growth of the tree the longer is the clear piece of lumber available. For this reason white pine, grown on rich loam soils, will probably bring a particularly good price as the market becomes more specialized. In close stands the limbs die out younger and the knots are consequently smaller. The wood formed outside of these knots is perfectly clear. For these reasons a mixture of some deciduous tree, which casts a shade and breaks off the dead branches, may bring about a better grade of lumber; but the increased price thus secured for lumber would probably not make up for the deficiency in yield over that produced by a pure pine forest.

¹Vt. Sta. Bul. 156, (1911), Vt. For. Serv. Pub. 4.

²For tables of growth see Appendix.

White pine may safely be planted on any soil in Vermont up to an elevation of 1,500 feet or northerly exposures, and 1,800 feet on southern and western exposures. On the better classes of soils, as those having considerable depth and mixture of loam, a spacing of 6 feet each way, giving 1,200 trees per acre, is sufficient. On the very dry, thin and sandy soils, a spacing of 5 by 6 feet is recommended, requiring 1,500 trees per acre.

Three-year transplants will usually be found most satisfactory, especially where there is any grass or brush growth. On worn-out pastures free from sod, two-year seedlings may be used with fair success. Three-year seedlings have no advantage over those a year younger.

RED OR NORWAY PINE¹—*Pinus resinosa*

This tree derives its name from the fact that it was first noticed near Norway, Maine. It is native, although not common, throughout northern New England, and is found scattered over Vermont, as on the shores of Lakes Memphremagog and Champlain, Island Pond, Barnet Pond, on the Ottaqueechee near Woodstock, and elsewhere. In mixture with white pine its growth, for the first thirty years, is the more rapid of the two.

The main advantages of the red over the white pine lie in the fact that it makes a better growth, especially on poor soils, prunes itself of branches earlier, is more hardy, and is less subject to injury by insects and fungi. It withstands a range of temperature of from -50° F. to $+105^{\circ}$ F., and thrives in sections where there are frosts every month of the year. It is usually found on soils where there is considerable sand and gravel, and for such soils, entirely lacking in clay or loam, is undoubtedly preferable to white pine for planting.

The Norway pine has a well developed tap-root when young, and develops strong laterals, so that it is usually very wind-firm. For this reason it may be planted not only where the soil is thin but on exposed sites. It is somewhat more exacting as regards direct sunlight than the white pine. Seedlings require direct sunlight and should not be planted in small openings of a forest or under any trees. It has been found, however, that Norway pine seedlings will stand sun exposure and weeds much better than will those of white pine.

¹Hawley & Hawes, *Forestry in New England* (Wiley); Woolsey & Chapman, *Norway Pine in the Lake States*, U. S. Dept. Agr., Bul 139. (1914).

Norway pine produces seed only once in 3 to 5 years. The cones are small and usually not plentiful, so that the seed is comparatively expensive. The young seedlings are particularly susceptible to damage by damping-off, and for these reasons nursery stock is usually more expensive than that of white or Scotch pine. Trees begin to produce seed at the age of about 25 years. Where the soil has been cleared of leaf litter good reproduction of this species is often secured 300 yards distant from seed trees, but the seed seldom germinates on a leaf litter.

After the seedling stage the Norway pine is remarkably free from enemies. On account of its thicker bark, it resists fire better than white pine, although young trees are, of course, killed by a hot fire. It is seldom attacked by the pine weevil and misshapen trees are very rare. It is also safe from the white pine blister-rust disease, and for this reason is recommended for planting in proximity to white pine suspected of being thus diseased.

While the wood of the Norway is somewhat redder in color, heavier and more resinous, it is sufficiently light, soft and straight grained to secure practically the same prices as white pine lumber. The wood is somewhat the stronger of the two. It is chiefly used for dimension stuff and house construction, also for boxes and shingles. Norway pine stumpage of old growth has sold as high as \$12 per thousand feet on a national forest in Michigan. In Vermont it is seldom separated from white pine. Second growth stumpage has sold for \$8.50 per thousand feet by the Champlain rule.

Norway pine should be planted pure, unless some slow growing tree which withstands shade is planted in mixture for the purpose of enriching the soil. The hemlock or native spruce could well be used in this way. When planted pure the trees should be spaced not nearer than six feet each way, since good pruning should be secured in this way. Three-year transplants are preferable, although two-year seedlings may be used where grass and weed growth is lacking.

SCOTCH PINE—*Pinus sylvestris*

This tree, which has been extensively planted in the eastern United States, is native throughout Europe, where several varieties are distinguished. It is common in Sweden and Russia and reaches an elevation of 2,700 feet¹ in the Vosges Mountains of eastern France.

¹Cannon, D., "Semer et Planter," Paris (1894).

and of 6,000 feet in the Maritime Alps and the Pyrennes.

Although it will grow on the driest and most acid soils, as well as on those rich in lime, it thrives best, like all other trees, on more favorable sites. There are probably few soils in Vermont too poor for this species up to an elevation of 2,000 feet. The Scotch pine has a strong root system, forms a dense crown cover, and is able to compete with practically all kinds of brush growth which it soon outgrows and smothers.

It has been established in Europe that the three trees which do the most to enrich the soil are beech, hornbeam and Scotch pine; hence this is a splendid species for reforesting worn-out and badly managed soils.

Its strong root system which enables it to monopolize the soil makes it disadvantageous to plant it in mixture with other species. Experimental mixtures with white pine have been made at the state forest in Sharon, but usually it should be planted pure.

The growth of the Scotch pine is very rapid after it becomes established, surpassing the white pine on very sandy sites. On the better loam sites the white pine grows about as well. The leaders of the Scotch pine sometimes make a growth of 40 inches, and often between 2 and 3 feet.

The quality of the wood is said to be best in the north of Europe, while in New England it can be compared fairly well with the native red or Norway pine. The wood as a fuel is in great demand by European bakers; it is also used for paper pulp, mine props, telegraph poles, railroad ties and for general building purposes. In France the lumber is considered superior to that of the American white pine.

Either two-year seedlings or three-year transplants may be safely planted on most lands. The latter should be used in competition with brush growth, but on open lands the former may be safely planted, being considerably stronger than two-year white pine seedlings.

The same spacing may be recommended as for white pine, but as the Scotch pines will usually be planted on the poorest sites, a spacing of 5 by 6 feet will be usually adopted.

EUROPEAN LARCH—*Larix Europoea*

While similar to our tamarack, this tree has some advantages

over, and some characteristics somewhat different from, its American relative. Unlike the tamarack it prefers a well drained, although not a dry, soil. In the Alps of France and Italy it reaches an elevation of 3,000 to 6,000 feet,¹ and may, therefore, be classed as essentially a mountain tree. So long as the soil is sufficiently deep and drained the larch will thrive, even if the soil is acid. In Europe it reaches a height of 100 feet and seems to live longer in mixture with spruce or fir. A mixture with deciduous trees is also good for soil protection.

The larch is fully as intolerant of shade as the tamarack and should only be planted in mixture with trees which it can outstrip. In a mixed stand in Connecticut where larch and pine are of the same age, the larch are taller, but the pine are somewhat larger in diameter.

The wood is so resinous that it is very durable in air and water. In Europe it is much used in boat making and for ties and poles. The best grades of wood are grown on northern slopes.

Two-year transplants are recommended for planting. They must be planted very early in the spring before the leaves begin to come out.

NORWAY SPRUCE—*Picea excelsa*

The Norway spruce, like the Scotch pine, is native throughout northern Europe, but is not peculiar to Norway any more than the pine is to Scotland. It is distinctly a mountain tree, occurring in the French Alps as high as 6,000 feet. However it thrives not only on thin mountain soils but also on the plains, provided the soil is not too dry. It grows more rapidly than our own red spruce and the lumber is apparently as good. It is much in demand in Europe, not only for general construction purposes but for such special uses as the manufacture of musical instruments. Wood fit for this work is only found in the mountains. Trees 130 feet high are not uncommon in France. One of the best plantations of this species in this country is that of the Billings' Estate at Woodstock, Vermont, now 36 years old. Tests of the wood of these trees, made by the International Paper Company, showed that it made a whiter and stronger pulp than our native spruce.

This species is well adapted for planting in Vermont on any sites

¹Cannon, D., "Semer et Planter," Paris (1894).

which are not too dry, up to an elevation of 2,500 feet. It can be especially recommended for planting openings in the forest, because a certain amount of shade does not interfere with its growth. On worn-out farm lands it is easily killed out by strong grass growth in dry seasons.

There are two objections to the Norway spruce. One is that in New England it does not seem to live much more than 50 years. This is not a serious objection from the standpoint of raising pulp, since an excellent crop may be secured in 30 to 40 years. The other objection is that it does not reproduce itself well. Although it seeds plentifully, seedlings in the neighborhood of old trees are rare. The tree has the same reputation in Germany where it is largely propagated by planting.

The young plants are very susceptible to the scorching influence of sunlight and for that reason planting on southern exposures should be done in the early fall, so that the trees may become established before encountering hot weather. On wet or cold sites, on the other hand, spring planting should be adopted. A spacing of 5 by 6 feet may be recommended, requiring 1,500 trees per acre. Only three or four-year transplants should be used.

WHITE SPRUCE—*Picea Canadensis*

This tree, which is native in northern Vermont, is one of the common and valuable timber trees of Canada. It has never attained importance with us, although it has been considerably planted for ornamental purposes. Its rapidity of growth and the fact that it is native recommend it for planting on sites similar to those recommended for Norway spruce. It is believed that its lumber is nearly if not quite as good, and that its reproductive capacity is much better.

Three-year transplants should be used, and planted 5 by 6 feet.

BALSAM FIR—*Abies balsamea*

The balsam fir is undoubtedly a tree which will be more appreciated in the future than it has been in the past and which may be recommended for planting under certain conditions in Vermont.

It is one of the most northerly trees of the continent, being confined to regions where the average summer temperature does not

exceed 70° F.¹ It reaches its best development in Maine where there is an average rainfall of 43 inches. In Vermont it is found chiefly in the northeastern counties, but it follows the upper slopes of the Green Mountains south the whole length of the State. Conditions of moisture and temperature are often similar in swamps and on the upper mountain slopes, and the ground in both cases is apt to be covered with sphagnum moss. On the mountains, however, the fir, like other trees, does not attain as large size as at lower elevations.

The balsam fir is short lived and consequently never reaches the proportions often attained by spruce. Trees 2 feet in diameter and 90 feet high are rare, although occasionally found on the lower slopes in Vermont. The foliage persists from 8 to 13 years, considerably longer than that of white pine. The root system is shallow, being similar to that of the spruce. The lateral roots extend out in all directions a distance of 5 feet or more.

Fir cones ripen in one year, while those of pine require two growing seasons. Ordinarily the tree begins to seed when 20 years old and the size of a good Christmas tree, but seed is more plentiful as the trees advance in age. The dominant trees, or those in the open, produce more seed than those crowded in a forest. Good seed years occur at intervals of 2, 3 or 4 years, according to the locality. The seed requires more moisture for germination than spruce, and where moisture conditions are suitable they germinate freely on rotten logs, mineral soil, moss, or even on hardwood leaf litter. In pure stands of balsam there are often from 200,000 to 300,000 seedlings to the acre.

The balsam requires less light than tamarack, white pine and arbor-vitae, but more light than either spruce or hemlock. Small dead firs under heavy shade are much more common than dead spruce. It will live under shade the first few years, but requires more light as it develops.

For good development the balsam requires a richer and moister soil than spruce. It reaches its largest size on flats where the soil is a moderately moist, deep loam. In wet swamps with acid soils and on pure sand it grows very slowly.

The balsam is particularly apt to be attacked by fungi which cause its decay and death at an early age. Because of rot this tree is much more apt to be broken off by wind than to be uprooted, as is

¹Zon.—Balsam Fir. U. S. Dept. Agr., Bul. 55 (1914).

the spruce. It is also especially susceptible to injury by fire, since the cambium is but slightly protected by the thin bark.

The balsam is a fairly rapid growing tree, though not as much so as the white pine. During the first 5 years its height growth is much slower than that of pine or Norway spruce, but from that point onwards until 60 years old, it averages, under favorable conditions, nearly a foot a year. Crowded in a forest its growth is somewhat less. The most rapid diameter growth is between the ages of 20 and 70 years, during which time it requires an average of 9 years for one inch of growth on the radius.

Balsam fir is used both for pulp and lumber. Because of its pitch content it is inferior for pulp purposes to spruce. Most pulp mills in the northeast now use balsam up to 40 percent mixed with spruce. For lumber purposes it is customary to sell balsam with spruce and there is usually no difference in prices, except for first grade.

Altogether there is considerable reason for planting balsam fir on cool, moist sites in Vermont, especially at elevations where white pine would not prosper. Three-year seedlings or four-year transplants should be used, and should be planted 6 by 6 feet.

WHITE ASH—*Fraxinus Americana*

This tree is scattered throughout the hardwood forests of Vermont but seldom forms pure stands. It prefers a moist, deep loam soil and is almost never found on dry, sandy sites. When grown in proper situations and with sufficient light, the white ash grows fairly rapidly.

Its seed production is prolific and natural reproduction near old trees is usually good, especially on a mineral soil rich in humus; but in most cases the seedlings die out for lack of light within a few years.

Ash lumber is in great demand for uses requiring bending qualities, and the best grades bring very high prices, e. g. \$22 per thousand for logs delivered. Stumpage brings from \$10 to \$12 per thousand.

It is a very easy tree to plant successfully and may be recommended especially where hardwoods have been cut clean. Two-year transplants should be used, and when planted pure should be spaced 5 by 5 feet, requiring 1,700 trees per acre. On cut-over lands where there is some brush growth, or where a tolerant species like spruce

is planted in mixture, white ash may be planted 6 by 6 requiring 1,200 trees per acre.

METHODS OF PLANTING

As most of the failures in forest plantations have been due to careless planting, it will be worth the while of the prospective purchaser to pay special attention to this section. The mattock or grub hoe is the best planting tool. Three methods of planting may be described.

(a) *Common method for planting 2 or 3-year nursery stock on worn-out farm land, or cut-over woodland, known as the cleft method.* The sod is first scraped away from a space about 1 foot square, then the mattock blade is buried, the handle raised and twisted to the right, making a hole at the left side of the blade. The roots of the seedling are distributed carefully in the hole under the blade. The blade is then removed and the soil is pressed with the foot firmly about the roots, so that there will be no air spaces. Care should be taken not to expose the roots to wind and sunlight before planting, since 5 minutes exposure is often enough to kill them, and to see that the trees are not planted deeper than they were in the nursery, since trees are often killed by burying.

(b) *Hole method.* In using four-year transplants or three-year seedlings, where the roots are long and irregular, greater care is necessary. After the sod is removed the earth should be taken out making a hole 6 or 8 inches deep and a foot in diameter. The roots are distributed in this hole, the tree being held carefully in an upright position. The fine soil is then replaced about the roots and the coarser soil on top pressed down as indicated in the preceding paragraph. In neither case is the sod replaced.

(c) *Furrow method.* In some cases, where strong grass land is planted to forest trees, as is sometimes done by water companies, the best way to insure the trees against competition with the grass is to plant them in furrows 6 feet apart across the piece. The planting in the furrows is done in one of the ways described under (a) and (b). Wherever stones are removed from the hole it is advisable to replace these on top of the soil around the trees to prevent evaporation.

CONVENIENT PLANTING CREW

For planting in the method described under (a), a crew of 4 or multiples of 4 will be found to be most efficient. Three of these men, equipped with mattocks, plant the trees, each following a straight line across the field, approximately 6 feet apart, sighting at stakes at the other end. The fourth man or boy carries the trees (the roots being covered with wet moss) in a basket or pail strapped over his shoulder, and he passes them out to the other three. Such a crew can plant from 2,000 to 4,000 trees a day according to the kind of land.

For planting in the method described under (b), a crew of 5 or 7 men is most efficient. With a crew of 7, 3 with mattocks, follow parallel lines, as in the previous case, and dig the holes, one man carries the trees and distributes them to the other 3 who plant them. This method is of course, slower. Such a crew will seldom plant more than 4,000 trees a day.

TIME OF PLANTING

There are two seasons in which forest planting can be done. Early spring planting usually gives the best results. Planting in the spring should begin as soon as the frost is out of the ground, for the reason that there is usually a dry spell in May or June. If the trees can be well established before such a time, a much larger percentage will survive. In 1913 the planting season began April 1, but usually in Vermont, the best time is between April 15 and June 1. Trees cannot be planted safely after they have begun to grow until the fall.

With some species, like Norway spruce on southern exposures, fall planting may be recommended. The chief point in its favor is that farmers are not quite as busy in the fall as in the spring, the highway work is not so strenuous and hence more men are available. On tracts where there is much planting to be done, fall planting doubles the length of time available. In Vermont the fall season extends usually from about August 20 to September 20.

Unpacking stock. The seedlings should be planted as soon as possible after arrival. If they cannot be planted at once they should be heeled in, near the site that is to be planted. A ditch, preferably under shade, may be dug, and, after the bundles are untied, the

roots should be covered with earth in this ditch, shading artificially if necessary.

Puddling. Just before planting a thick mud should be made, preferably with a slight admixture of clay. A few hundred trees are taken from the box or ditch and their roots are dipped in this mud. These are then placed in a basket or pail and their roots covered with wet moss or cloth.

SPACING

Dense planting is desirable so that the trees will begin to crowd each other at an early age and automatically prune each other. They will also make a better height growth than if the tops are wide spread. Although European foresters have in the past planted more closely, the general tendency is now toward a spacing of about 6 feet. Better grades of lumber can undoubtedly be secured by planting more closely, but with our poor markets for material removed in thinnings a quick production of coarse material bids fair to be more profitable.

Experience with all kinds of forest has demonstrated that nature provides more trees per acre on poor soils than on the better sites. In other words, the crowding is so intense on good soils that fewer trees survive than on the poorer sites. Some species, which are more tolerant of shade than others, need to be more crowded in order to prune themselves. For these reasons we recommend a spacing of 6 by 6 feet, making 1,200 trees per acre, for the pines and similar species, on soils of average depth and richness. On the poorest soils, or with tolerant species like the Norway spruce, a spacing of 5 by 6 feet, making about 1,500 trees per acre, is recommended.

Spacing	Trees per acre	Spacing	Trees per acre
4 by 4	2,722	6 by 6	1,210
5 by 5	1,742	7 by 7	888
5 by 6	1,452	8 by 8	680

ESTHETIC PLANTING

Most of the plantations made in Vermont have been for commercial purposes, and the methods thus far described have had only commercial operations in view. As Vermont lands come more and

more in demand for summer homes, forest plantations made upon esthetic principles will undoubtedly be valuable, and in many cases will very likely bring a price in excess of their commercial values. There is no question but that a natural forest is more beautiful than one which has been planted in straight rows. For esthetic purposes, therefore, a plantation should resemble as nearly as possible a natural stand. The trees should be spaced unevenly with some clumps and occasional openings. It is rather difficult to plant as many as 1,200 trees to the acre in this way. One of the best methods of planting irregularly is to scatter broadcast over an area as many pieces of wood as one wishes to plant trees. When the trees are set where these blocks fall there will be very few straight lines and the resulting forest will have a natural appearance.

PRICES OF NURSERY STOCK PER THOUSAND, SPRING, 1915

The prices of nursery stock for the present season are:

White pine	2-year seedlings ¹	\$2.50
White pine	3-year transplants ¹	5.00
Scotch pine	2-year seedlings	2.25
Norway or red pine	3-year transplants	5.75
Norway spruce	3-year transplants	5.00
White ash	2-year transplants	8.00

¹Seedlings are raised in the seed-beds for one or two years and are then transplanted. A year after this transplanting they are called three-year transplants.

These prices are for trees packed and delivered to the express company, but do not include the cost of transportation.

The state nursery has no intention of competing with private nurseries, and, therefore, does not sell large ornamental trees. Neither are orders accepted at the above prices for less than 500 trees of any one kind. However, in order to interest land owners who have not hitherto undertaken forest planting, a special offer of a sample package is made during the spring of 1915 on the following terms:

A sample package may contain 250 three-year white pine or Norway spruce transplants, choice to be made by the purchaser. No mixed lots will be allowed. These packages will be sent by parcel post, postage prepaid. The price per package will be \$2. This price is at a somewhat higher rate than for larger quantities, but it eliminates the necessity of driving to the express office for a small number of trees.

COST OF PLANTING

During the past 5 years the cost of labor has considerably advanced in Vermont, so that while nursery stock is cheaper the total cost of planting is as much, if not more, than formerly. The labor item for planting 1,000 trees on the state forests in 1913 was: Plain-field, \$6.00; Lyndon, \$4.23; Mendon, \$5.12; Townshend, \$5.15; Camel's Hump, \$5.58. These prices included labor at \$1.75 per day, and a foreman at \$2.00 or \$2.25 a day.

Estimating the average express charges as 25 cents per thousand, and the cost of hauling from the express office to the land at 10 cents per thousand, the cost of planting is as follows:

TABLE I. COST OF PLANTING 1,200 TREES PER ACRE

	Large plantations on fairly easy land, where labor costs \$4 per thousand		Small plantations on difficult land, where labor costs \$6 per thousand	
	2-year trees @ \$2.50	3-year trees @ \$5.00	2-year trees @ \$2.50	3-year trees @ \$5.00
Price of trees	\$3.00	\$6.00	\$3.00	\$6.00
Transportation	.40	.40	.40	.40
Labor	4.80	4.80	7.20	7.20
Total cost per acre	\$8.20	\$11.20	\$10.60	\$13.60

COST OF PLANTING 1,500 TREES PER ACRE

	Large plantations on fairly easy land, where labor costs \$4 per thousand		Small plantations on difficult land, where labor costs \$6 per thousand	
	2-year trees @ \$2.50	3-year trees @ \$5.00	2-year trees @ \$2.50	3-year trees @ \$5.00
Price of trees	\$8.75	\$7.50	\$8.75	\$7.50
Transportation	.55	.55	.55	.55
Labor	6.00	6.00	9.00	9.00
Total cost per acre	\$10.30	\$14.05	\$18.30	\$17.05

From the above examples it will be seen that the cost of planting an acre (with labor at \$1.75) may vary from \$8 for planting 1,200 two-year seedlings on easy land to \$17 for planting 1,500 three-year transplants on brushy, rocky land.

There are forestry companies which make a business of planting by contract. Their prices for planting 5 acres or over with 1,000 three-year transplants per acre range from \$13 per acre upward.

CARE OF FOREST PLANTATION

The most important thing in forest management is to furnish adequate fire protection. There are many tracts near railroads, or large lumber operations, where the danger is so great that forest planting is hardly justified. Whenever planting is done it is well to take measures for protection. Large plantations of conifers should be broken up into blocks of ten acres or less, either by plowed fire lines about one rod wide, or by planted belts of deciduous trees four rods or more in width. Plowed lines may be kept free from vegetative growth by harrowing two or three times a year. Belts of deciduous trees may be made more effective by annually raking up and burning the leaves and broken branches.

Stock should be excluded from plantations for at least eight years after planting. Cows do not eat pine tops but they break them off by rubbing against them when the trees are 2 to 5 feet high.

Sometime within the first 6 years of the life of a plantation it is usually desirable to make a "cleaning." This consists in removing any brush or inferior trees which are crowding the more valuable planted trees. Poplar and birch are especially apt to damage young pine by rubbing off the terminal buds. Blackberry and raspberry bushes often retard growth by shading the young trees. It is not necessary to remove the injurious growth from the plantation, but it is often sufficient to break it off near the base. This can be done at comparatively slight expense.

In all plantations of white pine a careful inspection should be made every summer for the weevil until the trees are above its reach.¹ This insect seldom kills the tree but invariably works in the main shoot causing it to wither and die, usually in July or early August. The next year one of the side branches straightens up and forms the leader, but there is always a slight crook in the tree. In badly infested regions the same tree is often attacked repeatedly and the numerous crooks give it a much deformed and stunted appearance. Of course its value for timber purposes is much diminished. The insect seems to prefer trees from 3 to 30 feet in height, though it occasionally attacks tall trees. Its ravages are worse in the southern range of the species than in Vermont. The adult is a reddish-brown beetle about half an inch long with a pronounced snout. The pupa is creamy white and of about the same length as its adult. The grub is also white and of

¹Vt. Sta. Bul. 156 (1911), Vt. For. Serv. Pub. 4.

varying length up to one-fourth of an inch, according to development. The infested top is badly decayed at the close of the season and is cut up with tunnels filled with borings. The first sign of the attack is disclosed by the wilting of the needles. The beetles deposit their eggs under the bark of the main shoots in May or June, and when the grubs hatch after a week or two they bore inward and in a downward direction to the pith. The grubs are much reduced by natural enemies, mostly parasitic insects. They transform into pupae and adults and during July and August of the same year, when the adults are fully matured, they bore their way out and seek suitable places in which to pass the winter.

The only way of fighting this insect is to cut off the infested top during June and July before the beetles have escaped. The safest way of destroying the weevils is to burn these tops; but as they often contain also a large number of minute insects which prey on the weevil a modification of this procedure has been suggested by Hopkins. A perfectly tight can is prepared with but one opening. The infested tops are placed in this can and the opening covered with a very fine wire mesh, so fine that the beetle cannot escape, whereas the parasites, which are much smaller, get out and attack other weevils. Either form of treatment must be repeated several successive years, as it is impossible to catch all the weevils in a single season.

TAXATION ON FOREST PLANTATIONS

No. 40 of the Acts of 1912 makes it possible for the owners of forest plantations and of young natural forests to determine in advance with some accuracy what the taxes are likely to be. Without knowledge of this kind one has little incentive to plant forests. This enactment and illustrations of its application follow.

AN ACT RELATING TO THE TAXATION OF YOUNG TIMBER

It is hereby enacted by the General Assembly of the State of Vermont

Section 1. An owner of land who wishes to classify the same under the provisions of this act shall make application for such classification to the state forester accompanied by such description of the land as the state forester may require. Application having been made in due form, the state forester shall examine the land in question, and if he finds the requirements hereinafter provided have been fulfilled, he shall issue a triplicate certificate of classification, the original to be filed in the office of the state forester, one copy in the office of the town clerk of the town in which the land is located, and one copy given the owner.

Sec. 2. Cut-over or other land fully stocked with forest trees not more than fifteen years old, except scattered trees the presence of which does not increase the assessed value of the property; cut-over or other land incompletely or partially stocked with forest trees not more than fifteen years old, when planted with a sufficient number of additional trees to assure a spacing of approximately six by six feet over the entire area; and open land planted with forest trees not less than one thousand

to the acre; provided in each case that the trees planted are of the following species: ash, basswood, oak, maple, white, Scotch or Norway pine, European larch, white or Norway spruce, or any other species approved by the state forester, and also provided that said state forester approves the manner in which the trees are planted, and provided further that said land is outside the limits of a city or village, shall be classified as forest land, and shall thereafter be taxed annually at the local rate on a valuation of the land alone, said valuation to be established by the local listers at the time of classification, but in no case to exceed three dollars an acre, said valuation to be maintained until the year 1950. In the year 1950 the land alone shall be revalued without regard to the above limit, and the valuation then established shall be maintained for a further period of fifty years, tax being levied annually on said valuation at the local rate. Whenever a commercial cutting is made a tax of ten percent shall be levied on the gross stumpage value of the amount cut.

Sec. 3. Classification as forest land for purposes of taxation shall be continued so long as proper forest conditions are maintained thereon. Use of said land for pasture; destruction by fire of the tree growth and failure of the owner to restore forest conditions; removal of tree growth and use of land for other purposes; or any other changed conditions which, in the opinion of the state forester, indicates that proper forest conditions are not being maintained, shall be considered sufficient grounds for cancellation of classification. When requested by the town listers, or whenever he may deem it necessary, the state forester shall examine classified forest land, and if he finds that the provisions of the law are not fully complied with, he shall forthwith cancel the classification of said land, sending notice of such cancellation to the town clerk of the town in which the land is located, and the owner thereof. Said land shall thereafter be taxed under the laws governing the general property tax unless it be granted reclassification as forest land at a subsequent date. Whenever a classification is cancelled, the owner of the land shall be required to pay a tax on the stumpage value of the standing timber amounting to one-half of one percent per annum for the entire number of years that said land has been under classification. This tax shall be in addition to any annual tax or yield tax which may have been paid, or may be collectible.

Sec. 4. All products of cuttings on classified land shall pay a yield tax as provided in sections 2 and 3 of this act except material cut for domestic use and which is not to be sold, or material removed in the form of thinnings to improve the condition of the remaining stand, and whose stumpage value does not exceed the cost of removal. Whenever a cutting, other than excepted above, is made the owner of the timber shall file with the local listers and the state forester, a sworn statement of the quantity which has been cut, and its stumpage value. If either the assessors or the state forester deem the value as stated too low the state forester shall determine the stumpage value and report the same to the listers and the owner. Should the owner be unwilling to accept the valuation as given by the state forester, he may refer the matter to a special board consisting of the first selectman and the town clerk of the town in which the land is located together with the state forester, whose decision with regard to the valuation shall be final.

Sec. 5. Sections 368, 369 and 370 and subdivision XIV of section 496 of the Public Statutes shall apply only to land planted to forest trees prior to January 1, 1913. Approved February 13, 1913.

A few illustrations of the manner in which this enactment operates.

1. A has a tract of 100 acres which is fully stocked with spruce from 1 to 15 years of age, which is now pastured. He wishes to have it classified. What must A do to have it classified; and what will his taxes amount to for the next 20 years?

He must agree to exclude all stock and make application for classification to the State Forester, who will have the land examined. If accepted, the land will then be assessed at not over \$3 an acre, and probably at this figure. If the tax rate is two percent, i. e. \$2 on a dollar, the annual tax on the land will be \$6. This tax in 20 years would amount to \$178.67 at 4 percent compound interest. If no cuttings were made during this period there would be no other tax.

2. B owns a tract of 200 acres, half of which is fully stocked with hardwoods from 1 to 15 years old; the other half is open pasture land. What must he do to have this land classified? What

would the tax on this amount to in 25 years if he removed 100 cords for his own use?

He can fence off the half which is fully stocked and apply to have this classified; or he may reforest the remainder and apply for classification for the whole area. If the whole area is classified at \$3 an acre the total valuation would be \$600. If the tax rate is 1.5 percent or \$1.50 on the dollar, the annual tax would be \$9. This tax at 5 percent compound interest for 25 years would amount to \$429.54. There would be no tax on the wood cut since it is used by the owner.

3. C owns 300 acres which is partially covered with young trees from 1 to 15 years old. He wishes to make an improvement thinning in 20 years and another cutting in 30 years. What must he do to have the land classified and what would his taxes amount to?

In order to have it classified he must interplant so that the spacing will be approximately 6 feet over the entire area. If the land is valued at \$3 an acre, and the tax rate is 1 percent or \$1 on the dollar, the valuation would be \$900 and the annual tax \$9. At 4 percent compound interest this would amount in 30 years to \$504.76. If he removes 1,000 cords in the thinning, which is worth on the stump \$1,000 and it costs to remove the wood \$1,500 there would be no tax on this wood. If at the end of 30 years he sells 500,000 feet of lumber, worth on the stump \$3,000, his tax on this cut will be \$300.

RETURNS FROM PLANTATIONS

The only way of forecasting the probable returns from a forest plantation is by means of yield tables. Unfortunately such tables have been made for comparatively few species. The following table for white pine gives conservative results for plantations, because it is based on natural, unthinned stands in New Hampshire.

TABLE 1. YIELD TABLE SHOWING YIELD IN BOARD FEET WHICH UNIMPROVED NATURAL SECOND-GROWTH WHITE PINE HAS PRODUCED IN NEW HAMPSHIRE¹

	Board feet per acre		
	Best pine soil	Medium soil	Poorest soil
20 yrs.	4,600	3,150	1,700
30 "	15,100	10,800	6,550
40 "	33,550	25,000	16,450
50 "	47,450	37,800	27,650
60 "	57,300	47,400	37,500
70 "	65,000	55,800	45,700
80 "	73,300	62,850	52,400
90 "	80,050	69,000	57,950

¹N. H. For. Com. Rpt. 1905-06.

TABLE II. MONEY YIELD TABLE—WHITE PINE

Soil	Stumpage at \$8 per M.		Stumpage at \$10 per M.		Stumpage at \$12 per M.	
	Quality I	Quality III	Quality I	Quality III	Quality I	Quality III
20 yrs.	\$ 36.80	\$ 13.60	\$ 46.00	\$ 17.00	\$ 55.20	\$ 20.40
30 "	120.80	52.00	151.00	65.50	181.20	78.00
40 "	268.00	132.00	335.50	164.50	402.00	198.00
50 "	379.20	220.80	474.50	276.50	568.80	331.20
60 "	458.40	300.00	573.00	375.00	687.60	450.00
70 "	527.20	365.60	659.00	457.00	790.80	548.40

The following yield table for white ash was made by a study of individual trees, and is not, therefore, as accurate as the pine table.

TABLE III. YIELD TABLE FOR PURE WHITE ASH BASED ON THE MEASUREMENTS OF RAPID GROWING INDIVIDUALS

Soil	Number of trees per acre		Volume per tree		Total volume per acre		Value of stand ¹	
	Quality I	Quality III	Quality I	Quality III	Quality I	Quality III	Quality I	Quality III
30 yrs.	160	90	14,400	\$ 86.40				
40 "	145	135	19,575	117.60				
50 "	135	185	24,975	150.00				
60 "	128	235	30,080	240.64				
70 "	121	275	33,275	266.16				
80 "	114	320	36,480	291.84				
90 "	105	365	38,325	306.56				

¹Value is based on a stumpage price of \$6 per thousand board feet for stands under 55 years, and of \$8 for older stands.

PROFIT FROM FOREST PLANTING

Table II indicates the probable financial returns from pine plantations of different ages on the best and poorest soils. In order to form an idea of the profit which these figures represent it is necessary to compute the cost of the plantation at these various ages. Table IV gives this data in three sets of figures based on an initial cost of planting of \$8, \$12 and \$16 per acre respectively. It is assumed in these calculations that the plantation would be classified under No. 40 of the Acts of 1912, that the land would be valued at \$3 per acre, and that the tax rate on the land is 2 percent. The investment in the land, cost of planting and taxes on the land are computed as 4 percent and the yield tax is based on an assumed stumpage value of \$10 per thousand.

TABLE IV. COST OF PRODUCTION PER ACRE

Soil	Cost of planting per acre					
	\$8		\$12		\$16	
	Quality I	Quality III	Quality I	Quality III	Quality I	Quality III
20 yrs.	\$ 27.47	\$ 24.59	\$ 36.23	\$ 33.35	\$ 44.99	\$ 42.11
30 "	51.10	42.59	64.06	55.55	77.02	68.51
40 "	89.05	71.96	108.25	91.16	127.45	110.86
50 "	131.83	111.99	160.27	140.43	188.71	168.87
60 "	184.30	174.50	226.88	216.58	268.46	258.66

Table V shows the profit which may be derived from one acre of forest plantation, stumpage figured at \$10 per thousand feet, as displayed in Table II, and the cost figured at three different rates for planting, as given in Table IV. It will be seen, for example, that a plantation costing \$12 an acre to form will produce in 50 years a profit of \$314 on the best soil and \$136 on the poorest soils over and above all costs, including taxes and compound interest at 4 percent.

TABLE V. PROFIT PER ACRE ABOVE 4 PERCENT COMPOUND INTEREST, CALCULATED FOR A STUMPAGE PRICE OF \$10 PER THOUSAND FEET

		Cost of planting per acre					
		\$8		\$12		\$16	
Soil	Quality I	Quality III	Quality I	Quality III	Quality I	Quality III	
20 yrs.	\$ 18.53	\$ 7.59 (Loss)	\$ 9.77	\$ 16.35 (Loss)	\$ 1.01	\$ 25.11 (Loss)	
30 "	99.90	22.91	86.94	10.05	73.98	3.01 (Loss)	
40 "	246.45	93.54	227.25	73.34	208.05	54.14	
50 "	342.67	164.51	314.23	136.07	285.79	107.63	
60 "	388.70	200.50	346.62	158.42	304.54	116.34	

VALUE OF LAND THAT CAN BE PLANTED PROFITABLY

The question often comes up as to how valuable land can be planted to white pine. Naturally the more valuable the land the lower rate of interest will be borne on an investment in planting. The table given below is based on a cost of planting of \$12 an acre. As shown above, this is a liberal figure, for the cost is quite as apt to be below as above this amount. It is also based on an assumed stumpage value of only \$8 per thousand, which is undoubtedly the minimum value especially for future calculations. If a larger value were assumed the percentage of profit would be correspondingly larger. However, under these conditions the table shows that land valued at \$10 an acre, planted at a cost of \$12 should yield 4 percent compound interest on the investment on the poorest soils, and on the best soils as high as 6 percent. On lands valued at \$3 an acre a 7 percent profit should be realized in 40 years.

It should be realized that it costs practically as much to plant an acre of the poorest soil as of the best, but that the returns are very much less. It must be borne in mind that these qualities of soil do not refer to agricultural conditions, the best forest soil often being on a par with the poorest agricultural soil, since the forester does not contemplate using land for forestry which could more profitably be utilized for agriculture. Bearing these things in mind, it will be realized that a person contemplating an investment in forest

planting will do well to study soil conditions, just as for farming, and invest his money in planting land which will produce the highest returns. He will see that whereas he may easily have a 5 percent investment on land costing \$10 an acre, if the soil is productive, it would be impossible for him to derive such a profit from the poorest land, if it cost him more than \$5 an acre. Tax listers should take these matters into consideration and list forest lands by a gradation of values according to their productive powers, in the same manner as with agricultural lands.

TABLE VI. PERCENTAGES OF PROFIT OBTAINABLE FROM WHITE PINE PLANTATIONS ON LAND OF DIFFERENT VALUES, WHERE PLANTING COSTS \$12 AN ACRE, AND WHERE LUMBER IS WORTH \$8 PER THOUSAND FEET ON THE STUMP

Age in years	Quality I				Quality III			
			Value of land per acre					
	\$1	\$3	\$5	\$10	\$1	\$3	\$5	\$10
	Percent				Percent			
20	4.5	4	3.5	3	0	0	0	0
30	7	6.5	6	5.5	4	3.5	3.5	3
40	7	7	6.5	6	5.5	5	5	4
50	6.5	6	6	5.5	5.5	5	5	4
60	6	5	5	4.5	5	4.5	4.5	4

In this connection the question naturally arises as to what is agricultural land and what is forest land. It must be admitted that there is no distinct line of demarcation. Much land in Vermont which was formerly profitable for sheep raising is today more profitable for timber production. The change is not so much due to the deterioration of the soil as to competition with Australia and other sheep raising sections, and to the growing scarcity of lumber throughout the United States. During recent years the number of cattle as well as sheep in Vermont has been steadily falling off. This has resulted in a diminishing demand for pasture and, consequently, a lowering of the profit derived from its use. True forest soil is the land which can never be used for agriculture; yet who can say what conditions a dense population of two or three centuries hence may bring about? All that we can hope to do is to predict for a period of 40 or 50 years what land can be profitably used for agriculture, and to advocate the use of the rest for forest production. Much land in Vermont is so steep, or rocky, or for other reasons unfavorable for agriculture, that it is practically certain that it will not be profitable for agriculture during the present century. Much of this land classifies as third quality forest soil and private owners should be conservative about investing money in reforesting it. It is chiefly a type of land which

should be owned and reforested either by the state or town, since the indirect benefits to the community would repay public expense though they would not compensate an individual owner.

There are in addition to these true forest soils, large areas of Vermont land, some of which have been used for agriculture in the past, and all of which may be profitably thus used at some future time. Any of this land which can be profitably cleared up and used for farming should be so used; but land that is far distant from a market, or upon which the cost of improvement would be excessive, or which for other reasons is not adapted to farming in the near future should be used for forest production. If after the growing of one forest crop conditions have so changed as again to make farming profitable on this land, it will be found that the forest has considerably enriched the soil. In some portions of Europe such an alteration of wood and farm crops has long been recognized as a legitimate form of agriculture.

It is not, however, a simple matter to determine at present just what land can be profitably used for agriculture. A progressive farmer, with due regard to labor income, might get a profit from a tract from which another man, considering only yield per acre, might derive no profit. In the same way, some pastures which are now liabilities rather than assets could be turned into assets by proper management. However, in dealing with average conditions of land we must also deal with average abilities to handle the same, and the average profits now being derived from them. The best way of determining the income from a pasture is to ascertain how much rental it would yield, since that depends somewhat upon the local supply and demand of pasture.

Table VII shows the accrued income on pasture land figured at 4 percent, compound interest for periods from 20 to 60 years. Comparing these figures with those in Table V, one may ascertain the relative profit from pasturing a certain area and from planting to forests. For example, a net income of 25c an acre on pasture, over and above interest on the value of the land and taxes, amounts to \$7.45 in 20 years at 4 percent compound interest. Comparing with Table V one finds that allowing \$12 an acre as the cost of planting the profit in 20 years on the best soil is \$9.77 per acre, and that on the poorest soil the loss is \$16.35 an acre. For such a short period the advantage in this case would be in favor of pasture.

A net income from pasture of \$1.00 an acre a year amounts in

40 years to \$95 while the net income from a plantation costing \$12 to establish ranges from \$73 to \$227 an acre. Evidently for such a long term a forest plantation is more profitable than pasturing even at a net income of \$1 which is rather a high rental for the class of land which will usually be planted to forests.

TABLE VII. ACCRUED INCOME FROM PASTURE RENTALS

Age in years	Net income per acre per year			
	\$.25	\$.50	\$ 1.00	\$ 1.50
20	7.45	14.90	29.80	44.70
30	14.00	28.00	56.00	84.00
40	23.78	47.50	95.00	142.50
50	38.20	76.40	152.80	229.20
60	59.40	118.90	237.80	356.70

COST OF RAISING PINE LUMBER

In the preceding pages the probable profit from forest planting has been discussed from the standpoint of the man who is to sell his lumber. There is even greater incentive for the manufacturer who uses a large amount of lumber to raise his own. By so doing he is sure of a sufficient local supply in the future to enable him to continue his business, and he can determine in advance fairly accurately what this supply will cost him. Without such a supply he must purchase from different sources, paying whatever is the market price at the time, and probably having to pay the freight rates for a considerable amount of it. He should realize that land owners in the future will be more intelligent about the selling of lumber than at present, and that bargains in woodlots will be increasingly scarce.

The local supply of lumber is likely to have an increasing influence on manufacturing business. It will be more and more difficult to compete with concerns having a local supply of lumber to meet their requirements.

The following calculation was made for a Vermont manufacturer who uses 800,000 board feet of pine annually, to determine how much it will cost to raise this amount annually. From Table I it is seen that it is fair to assume a production of 30,000 board feet per acre in 40 years. To cut 800,000 feet one must have 27 acres of 40-year old plantations. In order to cut 27 acres a year for 40 years a total of 1,080 acres is required, or, approximately, 1,100 acres.

Cost of 1,100 acres of land at \$3	\$ 3,300
Cost of planting 1,100 acres at \$10	11,000
	\$14,300
Value of land, \$3,300 at 4 percent compound interest for 40 years	\$12,540
Cost of planting, \$11,000 at 4 percent compound interest for 40 years	52,800
Tax of 1 percent on land value under No. 40, Acts 1912, at 4 percent compound interest for 40 years	3,135
10 percent yield-tax on stumpage, valued at \$15 per thousand	49,500
Total cost of growing 32,000,000 board feet	\$117,975
Average cost per 1,000 feet	\$ 3.68

If pine stumpage sells for \$15 per thousand at the end of 40 years, the manufacturer in question and his successors would save \$11.32 on a thousand feet, or \$9,056 annually. In the case of less productive land the cost of raising lumber would be correspondingly greater, as would also be the case, of course, if the land or the planting cost more than in the above example. On the other hand it is possible to improve upon all of these figures, though one is not likely to obtain first quality land for less than \$3 an acre. If stumpage is worth less than \$15 per thousand at the time of cutting, the yield-tax would be correspondingly less. With stumpage figured at \$12 the yield-tax would be \$38,400 instead of \$49,500, the cost of growing would be \$3.34 per thousand instead of \$3.68, and the profit would be \$8.66 per thousand instead of \$11.32.

In both of the cases above cited the profit in raising stumpage is predicated on the supposition that the manufacturer could purchase plenty of lumber in his own locality at the market price. As a matter of fact this will very seldom be the case, unless the manufacturer at least furnishes an example sufficient to interest others in this form of investment. In estimating his profit from planting we should, therefore, add freight charges to the stumpage price of most of the lumber purchased for a large business. If a concern, such as the one mentioned above, is obliged to buy half of its lumber from a distance, the freight charges on the same may well amount to \$1,000 a year, which must be added to the annual profit if the manufacturer raises his own lumber near at home.

In the sale of wood-using industries in the future a supply of

available growing timber suitable for the future needs of a business will be a very important asset, and a wood-using industry which has no such supply will find itself very much handicapped as compared with those in the vicinity of extensive forests.

It is said that the stockholders of one of the large Canadian paper companies, who are mostly English, always inquire first as to the area of the company's lands reforested, before they look into the items of receipts and expenditures. The time will come in this country when stockholders will demand that their business be run on a permanent basis, and that an annual inventory be submitted, showing the exact condition of all lands owned. Inventories of this sort would not be valuable assets to most companies at present.

SCHOOL ENDOWMENT FORESTS

In several foreign countries municipalities derive a considerable portion of their revenue from municipal forests. A village or city, being a permanent institution, can forego immediate returns for greater future returns and is, therefore, well adapted to manage forest property. This management is also usually safeguarded from local political vagaries by placing it entirely under the direction of the central forestry department, although the money goes directly to the municipal treasury which has entire control of expenditures. As examples of such communal or municipal forests, the following may be mentioned, although they are by no means exceptional.

Forbach, Baden, with about the same population as the Vermont town of Bethel, enjoys an annual revenue of nearly \$18,000 from its forest. Such a revenue would nearly eliminate taxation in Bethel.

It is often said that we cannot argue from conditions in foreign countries; but unless we admit that representative government is a failure there is nothing in this argument. Natural conditions here are equal to those in Europe. Our climate, soil and species of trees are as good or better than those in Europe. In fact, without much difficulty it can be shown that conditions for investing in forestry are better in New England at present than in Europe. While lumber is now worth about twice as much in Europe as with us, our prices are kept down by the immense supply of virgin timber in the west and by the fact that New England has no protective tariff, as has Germany. As soon as the virgin timber of the west is depleted, which will be before our present plantings are mature, our prices will be practically equal to those of Europe. In fact it is quite probable that the time is

coming when lumber will be even more costly than in Europe. The city of Zurich, Switzerland, recently purchased about 1,700 acres to add to its forest, paying an average of \$80 an acre for the land alone. Many other purchases at similar high figures might be mentioned. In New England, on the other hand, large areas can be secured for from \$2 to \$6 an acre. The State of Vermont recently purchased a tract of 3,000 acres, carrying a large amount of timber, for \$3.25 an acre. When it is said that forest planting in Europe brings comparatively small interest on the investment it must be remembered that there is a great disparity between land values here and abroad, and that now is the time to make investments of this kind. From what has already been said as to the relative fire risk in Vermont and the rest of New England, it may be seen that the opportunity for safe and profitable investments in forest planting are as good in Vermont, if not better, than elsewhere.

Several attempts have been made recently to popularize the idea of municipal forests in this country, notably those of the Massachusetts Forestry Association. To the writer the great difficulty with this movement has been to bring the public to distinguish between parks handled for recreation, which they are accustomed to, and forests handled chiefly for profit, but also available for recreation. Few Vermont towns can afford the luxury of a large park, but many could well make a long time investment. The purpose of No. 24 of the Acts of 1915, is to provide for municipal forests which would be without question for investment purposes. This law, therefore, provides for the establishment of school endowment forests by any towns so voting. Any tract of forty acres or over, owned by a town, may, upon the approval of the state forester, be set aside as a school endowment forest. The town may secure the trees to plant this land from the state nursery. Table V, giving the probable profits from plantations shows that plantations costing \$12 an acre to form should yield a profit in 50 years of from \$136 to \$314 an acre. Hence a town which planted 40 acres of the poorest forest soil might have a net profit over and above 4 percent on the money invested at the end of 50 years of over \$5,000 which re-invested at 5 percent would yield an annual income for the schools of \$250. If the town preferred it might invest the whole \$5,000 in school buildings. Suppose another town with 100 acres of medium land should plant 10 acres every 5 years. In 50 years, when the last of the area had been planted for four years, the first one would be ready to cut and the town might have a periodic income from that time



Plantation of Scotch Pine three years after planting. Land of the University of Vermont, Burlington.



Usual method of planting with Mattocks. (The sugar snow is no great disadvantage).

of about \$2,000 every 5 years. This, it must be remembered, is the profit over 4 percent compound interest on the whole investment. If a third town gradually acquired 500 acres for this purpose, and annually planted 10 acres for a period of 50 years, the future annual net income might easily be \$2,000 if the soil was of medium quality, or \$3,000 if it was of first class quality.

There are several classes of land which Vermont towns may be expected to use as school endowment forests.

(a) Many towns own lands surrounding their reservoirs which can not be cultivated for any length of time because they cannot be fertilized. A forest cover prevents evaporation, retards the melting of snow, and in other ways protects the water supply. Such land would be doubly useful if planted with forests, because they would in time yield a revenue.

(b) Occasionally tracts of cut-over forest lands are sold for taxes. Such lands are usually of third quality soil and are, therefore, less profitable for planting than more expensive lands. However, the town can afford to bid these in at a price which the private individual might not care to pay because of the indirect value to the town from having the land productive and the water supply protected. It should be remembered that a tax title is not very good and it is well to pay a little more for a quit claim deed.

(c) In many towns there are public spirited men who would be glad to endow the schools of their town either by outright gift of land or by willing such land to the town. It might be well for the town clerk in each town to canvass his town for such donations.

(d) In many towns there are abandoned farms which are practically non-productive, on which the taxes amount to very little. In many cases it would be good policy for the towns to buy some of these abandoned lands and reforest them. They would in that way become productive and would in time furnish more remunerative work to the people of the town than they ever will in their present condition, and because of this fact the population of the town can be increased.

The question of establishing a school endowment forest should be brought up before every town. The new law reads as follows:

NO. 24 OF THE ACTS OF 1912

AN ACT TO PROVIDE FOR SCHOOL ENDOWMENT FORESTS

It is hereby enacted by the General Assembly of the State of Vermont.

Section 1. Towns and cities may at any legal meeting grant and vote such sums of money as they may deem best for the purchase, management and improvement of lands for the purpose of growing wood and timber thereon.

Section 2. Any town or city having in its possession, either through donation, purchase or forfeiture for taxes, a tract of land of not less than forty acres,

may have the same examined without cost by the state forester for the purpose of determining whether the same is suitable for a school endowment forest. If, upon examination, the state forester decides that it is suitable for such purposes, it shall be designated as a school endowment forest, and the state forester shall give advice as to what trees shall be planted thereon and as to the subsequent management thereof.

Sec. 3. The state forester is authorized to distribute annually 150,000 trees from the state nursery among towns for the planting of school endowment forests, said trees to be sold at the same prices as those to private individuals.

Sec. 4. School endowment forests shall be managed under the direction of the state forester, and only such trees may be cut as he may, from time to time, designate. The protection of the forest shall be under the town forest fire warden, who shall be compensated for his services by the town at the same rate as is paid for fighting forest fires, upon the approval of his account by the state forester.

Sec. 5. All money received for the sale of lumber, wood or other produce from a school endowment forest, shall be deposited with the treasurer of the town owning the same, who shall render an annual report of all money so received to the state treasurer.

Approved April 1, 1915.

APPENDIX

HEIGHT GROWTH

The best data available as to the height growth of the species recommended is included in the following table:

TABLE VIII

Height growth in feet of species recommended for planting.						
Age in years	White pine ¹			Norway pine ²	Balsam fir	White ash
	Upland pasture	Sandy soil	Wet swamp	Average ³	Average ³	Average ⁴
10	9	5	4	12	..	..
20	24	23	16	35	14	39
30	40	36	28	58	25	53
40	53	44	39	70	36	63
50	64	51	48	77	45	71
60	73	57	54	82	52	77
70	80	61	60	85	59	82
80	84	65	65	88	64	86
90	89	..	70	90	68	90
100	91	..	..	91	71	93

¹Mass. State Forester, "Forest Mensuration of White Pine."

²U. S. For. Serv. Bul. 139 (1914), Bayfield Co. Wis.

³U. S. For. Serv. Bul. 55 (456 trees in Maine).

⁴Vt. Sta. Bul. 176 (1914), Vt. For. Serv. Pub. 13.

DIAMETER GROWTH

Diameter in inches of trees of different ages

TABLE IX

Age in years	White pine ¹		Norway pine ²	Balsam fir ²	White ash ⁴
	Quality I	Quality III	Average	Average	Average
10	1.7	1.0	.6	..	..
20	4.0	2.3	2.8	1.2	4.1
30	6.4	3.9	5.7	2.7	6.1
40	8.6	5.5	8.0	4.1	7.9
50	10.8	7.0	9.9	5.5	9.5
60	12.8	8.6	11.7	6.7	10.8
70	14.7	10.1	13.2	7.9	11.8
80	16.5	11.7	14.6	8.9	12.6
90	18.2	13.2	15.9	9.9	13.3
100	19.8	14.5	16.9	10.7	13.8

¹Report of Forest Commissioner of N. H., 1905-06.

²U. S. Dept. Agr. Bul. 139 (1914).

³U. S. Dept. Agr. Bul. 55 (1914).

⁴Vt. Sta. Bul. 176 (1914), Vt. For. Serv. Pub. 13.

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BURLINGTON, VT.

BULLETIN No. 189

JUNE, 1915

Commercial Feeding Stuffs
Concerning the Corn Crop

BURLINGTON:
FREE PRESS PRINTING COMPANY,
1915

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Director's and State Forester's offices, chemical, horticultural and dairy laboratories are in Morrill Hall at the head of Main street; botanical and bacteriological laboratories are at Williams Science Hall, University Place; veterinary laboratories are at 499 Main street.

University farm and buildings are on the Williston road, adjoining the University grounds on the east.

*In cooperation with Bu. An. Ind., U. S. Dept. Agr.

BULLETIN 189: COMMERCIAL FEEDING STUFFS

By J. L. HILLS, C. H. JONES, C. G. WILLIAMSON AND

G. F. ANDERSON

CONCERNING THE CORN CROP

By J. L. HILLS

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SUMMARY

Six hundred and seventy samples of commercial feeding stuffs were drawn in the winter and early spring of 1914-1915 from dealers' stocks. On the whole they proved to be of good grade. Only twelve lots failed to make good their makers' guaranties only four of which were deficient to the extent of two percent and only one of which was seriously deficient. But very few unguarantied goods were found on sale. Speaking broadly, feed manufacturers and jobbers nowadays tell the truth as to the protein contents of the feeds they sell. The protein analyses and ingredient contents of the various feeding stuffs are shown on pages 302 to 324, and the discussion of the analytical results appears on pages 325 to 328 together with other "information in relation to the character, composition, value and use" of sundry feeding stuffs.

A special article concerning the corn crop appears on pages 324 to 381.

II. INTRODUCTION

The sampling agents of the Station visited 73 towns and villages in Vermont in late December, 1914, and early January, 1915, and in March and April, 1915, and drew 670 samples from dealers' stocks, representing over 350 brands of goods which either are subject to or exempt from the necessity of guaranty. All of these samples were examined chemically for protein. Both guaranteed and unguaranteed goods were analyzed; the former to determine so far as might be learned their purity, as well as the maintenance of the standards fixed by the manufacturers; the latter to determine, if possible, whether as a matter of fact the goods were pure and, hence, not subject to guaranty.

Only the protein contents were determined. In general it may be said that so far as the maintenance of protein guaranties is concerned, the results of the present inspection are extremely satisfactory. Very few shortages occurred, and these save in one case were not serious ones.

The reader who may be interested in the economics of feed purchase is referred to matter on pages 34 to 44 of bulletin 144, as well as to that on pages 582 to 590 of bulletin 152. Full descriptions of the nature and manufacture of the various goods offered on the Vermont market will be found on pages 22 to 34 of bulletin 144, together with a discussion of the advisability or inadvisability of their purchase, as the matter appealed to the writer when the bulletin was written.

SYNOPSIS OF THE PUBLIC STATUTES DEALING WITH FEEDING STUFFS

The Vermont feeding stuff law was slightly amended by the General Assembly of 1912. As it now reads its essentials are as follows:

Sections 4983-4. *Definition of the term "concentrated commercial feeding stuff"*; including the common feeds other than hay, straw, whole seeds and unmixed meals, wheat, rye and buckwheat offals.

Section 4985. *Statement of contents*; net weight, brand name and address of manufacturer, minimum percentages of crude protein and crude fat, maximum percentage of crude fiber, and the *specific name of each ingredient used in manufacture*.

Section 4986. *Illegal sales; penalty*. The omission of the guaranty, a material overstatement of the actual protein or fat contents or understatement of the actual fiber contents, *and the omission of or incorrect statement of the specific name of each ingredient* are forbidden; fine, not to exceed fifty dollars for the first or one hundred dollars for each subsequent offense.

Section 4987. *Adulterations; exceptions; penalty.* The adulteration of whole or ground grain, or of bran, middlings or mixed feed with offals, unless the fact is stated on each package, and the inclusion of more than two percent by weight of weed seeds unless stated on each package, are forbidden; fine, not less than twenty-five dollars nor more than one hundred dollars.

Section 4988. *Appropriation; expenses; report.* Five hundred dollars annual appropriation; annual financial statement to be published by the Station.

Section 4989. *Prosecutions.* Notice to dealer giving thirty days time wherein to comply with law; failing which, report is made to state's attorney; no prosecution in relation to quality if the same is substantially equivalent to the guaranty.

Section 4990. *Collection of samples.* Authorization to enter and take samples; not less than five percent of entire lot to be sampled, thoroughly mixed, sealed and labelled; samples to be taken in duplicate if requested by the dealer.

Section 4991. *Analyses of samples; publication.* One sample of each brand to be analyzed; results, together with additional information in relation to the character, composition, value and use of feeding stuffs, shall be published.

Section 4992. *Exception.* Act does not apply to persons purchasing for their own use and not for sale.

Section 4993. *Obstructing director; penalty.* Provision against hindrance in execution of law.

On the whole the law is well observed at present. In a few cases, particularly when mixtures are locally made in a small way by Vermont dealers, the packages do not declare their contents in terms of ingredients as is now required by law. Unguarantied goods are infrequent at the present time and overguaranties are uncommon; but overstatements in advertising still occur. The law cannot control extravagant statements in the press or elsewhere. It is for the buyers to look askance thereat and to ask the Station as to the facts.

It is not generally appreciated that there is a federal law which aids in preventing misbranding, misstatement and adulteration of such goods as may enter into interstate commerce. The state law, of course, cannot hold outside of state lines; but serious cases of fraud may be reported to federal authorities. In this way local dealers who sell in good faith need not be troubled and the parties actually responsible for illegal sales may be reached.

STANDARDS: AVERAGE COMPOSITION

A standard is defined to be "a measure of quality established by law or by general usage or consent; any type, model, example or authority with which comparison may be made; any fact, thing or circumstance forming a basis for adjustment and regulation." Now standards, i. e., "measures of quality," "examples with which comparison may be made," are of service in connection with the use of feeding stuffs. Thus one is able the better to pass judgment on the worth of a given sample. The percentages of protein, fat and fiber form in part the basis of judgment in this connection. If a given sample is of good appearance, neither moldy, rancid nor in other ways spoiled, is mechanically in good condition, is free from objectionable foreign matter and carries approximately the protein and fat percentages and not materially more than the fiber content shown below, it is probably safe to assume it to be of standard quality.

The following table of averages indicates closely the average composition of the goods more commonly sold.

	Protein	Fat	Fiber
I. GOODS CARRYING MORE THAN 30 PERCENT PROTEIN			
Cottonseed meal (choice)	41.	9.5	7.
Cottonseed meal (prime and good)	36.	8.	8.
Linseed meal (new process)	36.8	2.8	9.
Linseed meal (old process)	34.1	7.6	9.
Distillers' dried grains (first grade)	31.6	13.1	12.
II. GOODS CARRYING 25 TO 30 PERCENT PROTEIN			
Buckwheat middlings	29.1	7.5	5.
Distillers' dried grains (second grade)	27.5	11.5	13.
Brewers' dried grains	26.1	7.1	12.
Malt sprouts	26.5	1.5	12.5
III. GOODS CARRYING 20 TO 25 PERCENT PROTEIN			
Gluten feeds	23.7	3.	7.5
IV. GOODS CARRYING 15 TO 20 PERCENT PROTEIN			
Molasses feeds (as a class) exclusive of horse feeds ..	16.2	3.4	12.
Wheat middlings	17.1	5.1	5.
Wheat mixed feed	16.2	4.8	9.
Wheat bran	15.2	4.7	10.
V. GOODS CARRYING 10 TO 15 PERCENT PROTEIN			
Molasses feeds for horses (as a class)	12.4	3.3	15.
Fortified oat feeds	12.9	3.8	8.
Alfalfa meals	13.1	1.3	28.
Hominy meal	10.5	8.4	4.5
Ground oats	10.6	4.8	10.
VI. GOODS CARRYING 5 TO 10 PERCENT PROTEIN			
Corn and oat feeds (as a class)	9.2	5.1	9.
Provender	9.2	4.3	6.
Oat feeds (as a class)	6.8	3.1	20.
Corn meal	8.9	3.4	2.
Dried beet pulp	8.	0.3	18.
VII. POULTRY FEEDS			
Meat scraps	50.	15.	..
Meat and bone meals	40.	10.	..
Mashes	16.	4.	7.
Chick feed	12.	3.	3.
Scratch feed	11.	3.	3.

III. RESULTS OF INSPECTION

SAMPLES DRAWN IN DECEMBER, JANUARY, MARCH AND APRIL

The following tabular matter (pages 302 to 324) displays protein guaranties and contents. The feeds are classified according to their nature, and *the brands are arranged within each class in the order of their protein contents.* Definitions and ingredient statements also appear in juxtaposition to the analyses on the opposite page.

COTTONSEED MEALS

MANUFACTURER OR JOBBER	BRAND	GUAR.	ANAL.
Chickasha Cotton Oil Co., Chickasha, Okla.	Chickasha Quality	43.	43.1
Memphis Cottonseed Products Co., Memphis, Tenn.	Selden	41.	42.5
S. P. Davis, Little Rock, Ark.	Good Luck	41.	41.9
W. Newton Smith, Baltimore, Md.	Dirigo	38.6	41.6
J. E. Soper Co., Boston, Mass.	Pioneer	41.	41.6
J. E. Bartlett Co., Jackson, Mich.	Bartlett's Michigan Farmers'	41.	41.6
F. W. Brod�� Co., Memphis, Tenn.	Owl	41.	41.2
J. E. Soper Co., Boston, Mass.	Pioneer	41.	41.
Humphreys, Godwin Co., Memphis, Tenn.	Dixie	38.6	41.
Union Seed & Fertilizer Co., (address not given)	Choice	41.2	41.
C. L. Montgomery Co., Memphis, Tenn.	Canary	38.	41.
Union Brokerage & Commission Co., Vicksburg, Miss.	Durjan	41.	40.8
Humphreys, Godwin Co., Memphis, Tenn.	Forfat	38.6	40.8
Humphreys, Godwin Co., Memphis, Tenn.	Dixie	38.6	40.3
J. E. Soper Co., Boston, Mass.	Pilgrim	38.5	40.3
F. W. Brod�� Co., Memphis, Tenn.	Owl	41.	40.
Humphreys, Godwin Co., Memphis, Tenn.	Dixie	38.6	39.7
W. Newton Smith, Baltimore, Md.	Dirigo	41.	39.7
Buckeye Cotton Oil Co., Cincinnati, Ohio	Buckeye Prime	38.6	39.
Buckeye Cotton Oil Co., Cincinnati, Ohio	Buckeye Prime	38.6	38.9
W. Newton Smith, Baltimore, Md.	Dirigo	38.6	38.4
American Cotton Oil Co., Jackson, Tenn.	Red Tag	38.6	37.2

LINSEED MEALS

American Linseed Co., New York, N. Y.	Hypo Pure	36.	38.6
American Linseed Co., Chicago, Ill. ....	.....	36.	36.8
American Linseed Co., New York, N. Y.	Old process	34.	36.2
American Linseed Co., Chicago, Ill. ....	.....	36.	35.4

DEFINITIONS¹ OF FEEDING STUFFS AND "INGREDIENTS"

The feeding stuffs law, as amended by the General Assembly of 1912, requires that "the specific name of each ingredient used in its manufacture" be stated on "each lot or parcel of concentrated commercial feeding stuff." Manufacturers have not in every case complied with this feature of the law.

Cottonseed meals, linseed meals, gluten feeds, distillers' dried grains, brewers' dried grains, malt sprouts, dried beet pulp, hominy feed, ground beef or fish scraps; all of them "concentrated commercial feeding stuffs" as defined in Section 4983 P. S., if true to name and not sold under some trade name not indicative of their true nature, are not held to be compounded materials and, hence, need no special statement.

Cottonseed feeds, molasses feeds, oat feeds, corn and oat feeds, proprietary mixtures and mixed feeds (not wheat mixed feeds free from adulteration or from wheat screenings), condimental stock and poultry foods, and stock feeds, must now carry a statement of their ingredients. Lack of funds prevents any careful survey of the samples to determine whether or not as a matter of fact the statements of ingredients made by the manufacturer are accurate. On account of its lack of information the Station expresses no opinion as to whether in any given case manufacturers' statements in this respect are or are not reliable. However, it sees no reason to allege inaccuracy in any case. The manufacturers' statements occur on the odd numbered pages from 303 to 319.

Cottonseed meal is a product of the cottonseed only, composed principally of the kernel with such portion of the hull as is necessary in the manufacture of oil; provided that nothing shall be recognized as cottonseed meal that does not conform to the foregoing definition and that does not contain at least 36 percent of protein.

Choice cottonseed meal must be finely ground, not necessarily bolted, perfectly sound and sweet in odor, yellow, free from excess of lint, and must contain at least 41 percent of protein.

Prime cottonseed meal must be finely ground, not necessarily bolted, of sweet odor, reasonably bright in color, yellow, not brown or reddish, free from excess of lint, and must contain at least 38.6 percent protein.

Good cottonseed meal must be finely ground, not necessarily bolted, of sweet odor, reasonably bright in color, and must contain at least 36 percent protein.

Linseed meal is the ground residue after extraction of part of the oil from ground flaxseed. The "old process" meal is made from crushed flaxseed which has been heated and subjected to hydraulic pressure; the "new process" meal is made from crushed flaxseed which has been extracted after heating by repeated leachings with light naphtha, all traces of which are removed by steam treatment. The latter goods carry but half the fat content of the former and usually from one to two percent more protein.

¹In the main those adopted by the Association of Official Feed Analysts.

LINSEED MEALS (cont.)

Spencer, Kellogg & Sons, Minneapolis, Minn.	Old process	33.	35.3
American Linseed Oil Co., New York, N. Y.	Old process	34.	35.1
Midland Linseed Products Co., Minneapolis, Minn.	Old process	32.	34.6
Spencer, Kellogg & Sons, Minneapolis, Minn.	Old process	33.	34.6
Midland Linseed Products Co., Minneapolis, Minn.	Ground Cake	32.	34.2
Toledo Seed & Oil Co., Toledo, Ohio	Major brand, old process	30.	33.1
American Milling Co., Peoria, Ill.	Amco, old process	30.	32.9
Toledo Seed & Oil Co., Toledo, Ohio	Major brand, old process....	30.	32.7
Toledo Seed & Oil Co., Toledo, Ohio	Major brand, old process	30.	32.4
American Milling Co., Peoria, Ill.	Amco, old process	30.	32.

GLUTEN FEEDS

Corn Products Refining Co., Chicago, Ill.	Diamond Corn Meal	40.	45.4
Corn Products Refining Co., Chicago, Ill.	Buffalo	23.	28.8
Corn Products Refining Co., Chicago, Ill.	Buffalo	23.	27.6
Clinton Sugar Refining Co., Clinton, Iowa	Clinton Corn	23.	27.2
Clinton Sugar Refining Co., Clinton, Iowa	Clinton Corn	23.	26.8
American Maize Products Co., New York, N. Y.	Cream of Corn	23.	26.1
Clinton Sugar Refining Co., Clinton, Iowa	Clinton Corn	20.	25.4
Douglas Co., Cedar Rapids, Iowa	Douglas Corn	20.	25.3
American Maize Products Co., New York, N. Y.	Cream of Corn	23.	25.2
Clinton Sugar Refining Co., Clinton, Iowa	Clinton	20.	25.
J. C. Hubinger Bros. Co., Keokuk, Iowa	KKK Corn	23.	24.6
Douglas Co., Cedar Rapids, Iowa	Douglas Corn	23.3	24.6
Douglas Co., Cedar Rapids, Iowa	Douglas Corn	23.3	23.4

DISTILLERS' DRIED GRAINS

Ublko Milling Co., Cincinnati, O.	Fourex Grains	31.	33.8
Ublko Milling Co., Cincinnati, O.	Fourex Grains	31.	33.1
J. W. Biles Co., Cincinnati, O.	Fourex Grains	31.	33.1
Hottel & Co., Milwaukee, Wis.	Hector	30.	32.3
Ajax Milling & Feed Co., Hammond, Ind.	Ajax Flakes	30.	32.
Dewey Bros. Co., Blanchester, O.	Corn D 3 Dewey	28.3	31.6
New York & Kentucky Co., Rochester, N. Y.	Columbia Corn	30.	31.4

Corn starch byproduct with corn bran (the entire coating of the corn kernel) is that portion of commercial shelled corn that remains after the separation of the larger part of the starch and the germ by the processes employed in the manufacture of corn starch and glucose. It may or may not contain corn solubles.

Gluten feed is a product obtained in the manufacture of starch and glucose from corn and is a mixture of gluten meal, corn bran, germ residues, and, permissibly, "steep water" residues. It consists largely of the flinty portion of the outer coatings of kernel, being essentially the corn grain with its starchy portion largely removed.

Distillers' dried grains are the dried residue from cereals obtained in the manufacture of alcohol and distilled liquors. The product shall bear the designation of the cereal predominating.

Brewers' dried grains are the properly dried residue from cereals obtained in the manufacture of beer.

DISTILLERS' DRIED GRAINS (cont.)

Ajax Milling & Feed Co., Hammond, Ind.	Ajax Flakes (1)	30.	31.1
Clarke Bros. & Co., Peoria, Ill.	Empire State Dairy Feed (2)	30.	30.7
Clarke Bros. & Co., Peoria, Ill.	Empire State Dairy Feed (2)	28.	30.5
Dewey Bros. Co., Blanchester, O.	Eagle 3 D	30.	30.1
Hottelet & Co., Milwaukee, Wis.	Hector	30.	29.6
Clarke Bros. & Co., Peoria, Ill.	Empire State Dairy Feed (2)	28.	28.9
Dewey Bros. Co., Blanchester, O.	Dewey's	28.	26.7
Dewey Bros. Co., Blanchester, O.	Corn D 3 Dewey	26.	26.5

BREWERS' DRIED GRAINS

Michigan Sugar Co., Saginaw, Mich.	Bull	27.2	28.9
Farmers' Feed Co., Buffalo, N. Y.	Bull	27.2	27.9
Farmers' Feed Co., Buffalo, N. Y.	Bull	27.2	27.9
Hottelet & Co., Milwaukee, Wis.	Holstein	25.	27.4
Haftenreffer & Co., Boylston Brewery, Boston, Mass.		20.5	25.9

PROPRIETARY FEEDS

Mayflower Mills, Fort Wayne, Ind.	Butterfat Meal (3)	24.	30.
Chas. M. Cox Co., Boston, Mass.	Wirthmore Balanced Ration for Milch Cows (4)	25.5	29.8
Burlington Flouring Co., Burlington, Vt.	Perfection Dairy No. 1 (5) ...	26.	28.5
Chas. M. Cox Co., Boston, Mass.	Wirthmore Balanced Ration for Milch Cows (4)	25.5	27.6
Chapin & Co., Hammond, Ind.	Unicorn Dairy Ration (6) ...	26.	27.2
Chapin & Co., Hammond, Ind.	Unicorn Dairy Ration (6) ...	26.	27.2
E. Crosby & Co., Brattleboro, Vt.	Crosby's Ready Ration (7) ..	25.	27.2
Chesbro Milling Co., Salamanca, N. Y.	Peerless Dairy Ration (8) ...	22.	27.2
City Grain Co., St. Albans, Vt.	Farmers' Favorite Ration (9) ..	22.6	27.2
R. H. McEwen Mfg. Co., Ogdensburg, N. Y.	Pontiac Dairy Ration (10) ..	24.	26.6
Dewey Bros. Co., Blanchester, O.	Dewey's Ready Ration (11) ..	25.	26.3
Mayflower Mills, Fort Wayne, Ind.	Waumbeck Milk Makers' Mix- ture (12)	23.	25.6
Mayflower Mills, Fort Wayne, Ind.	Waumbeck Milk Makers' Mix- ture (12)	23.	25.4
Mayflower Mills, Fort Wayne, Ind.	Waumbeck Milk Makers' Mix- ture (12)	25.	25.4
Ubiko Milling Co., Cincinnati, Ohio	Union Grains (13)	24.	25.4
Ubiko Milling Co., Cincinnati, Ohio	Biles' Ready Dairy Ration (14)	24.	24.6
Ralston Purina Co., St. Louis, Mo.	Purina Cow Chow (15)	24.	24.6
Chittenden Mills, Jericho, Vt.	Reavy's Dairy (16)	24.	24.3
Ubiko Milling Co., Cincinnati, Ohio	Union Grains (13)	24.	24.1
Quaker Oats Co., Chicago, Ill.	Blue Ribbon Dairy (17)	25.	24.
Ralston Purina Co., St. Louis, Mo.	Purina Cow Chow (15)	24.	23.9
Quaker Oats Co., Chicago, Ill.	Blue Ribbon Dairy (17)	25.	23.8
Elmore Milling Co., Oneonta, N. Y.	Elmore Milk Grains (18)	25.	23.8
Quaker Oats Co., Chicago, Ill.	Blue Ribbon Dairy (17)	25.	23.2

Proprietary feeds are admixtures made by manufacturers of a greater or less number of feeding stuffs, high grade, low grade or both. A statement of the ingredients, but not the proportions or "formula," must be declared upon each package.

The following statements have been secured touching the lots sampled in the winter and early spring of 1914-15, being the claims made by the manufacturers as to ingredient contents. For reasons indicated on page 303 the Station cannot assert, nor does it deny, the accuracy of their statements. The numbers in parenthesis, e. g. (1), refer to the analyses on the opposite page.

(1) *Ajax Flakes*, Ajax Milling and Feed Co., Hammond, Ind. "Corn distillers' grains."

(2) *Empire State Dairy Feed*, Clarke Bros. & Co., Peoria, Ill. "Corn distillers' dried grains."

(3) *Butterfat Meal*, Mayflower Mills, Fort Wayne, Ind. "Cottonseed meal, old process, oil meal, pure wheat middlings, pulverized grain screenings."

(4) *Wirthmore Balanced Ration for Milch Cows*, Charles M. Cox Co., Boston, Mass. "Cottonseed meal, Buffalo gluten, linseed meal, malt sprouts, distillers' grains, bran, and hominy or corn meal, 0.75 percent fat."

(5) *Perfection Dairy Feed, No. 1*, Burlington Flouring Co., Burlington, Vt. "Cottonseed meal, old process linseed meal, hominy, gluten feed, dried beet pulp, brewers' dried grains, flour middlings and bran and 0.75 percent salt." Manufacturer has not been placing statement on packages, not being informed as to the requirements of the law, but will do so hereafter.

(6) *Unicorn Dairy Ration*, Chapin & Co., Hammond, Indiana. "Corn distillers' grains, cottonseed meal, linseed meal, hominy meal, gluten feed, cornstarch byproducts with corn bran, barley feed, malt sprouts, brewers' grains and pure wheat bran."

(7) *Crosby's Ready Ration*, E. Crosby & Co., Brattleboro, Vt. "Distillery dried grains, cottonseed meal, oil meal, malt sprouts, wheat bran, wheat middlings, hominy feed and 0.50 percent salt."

(8) *Chesbro's Peerless Dairy Feed*, Chesbro Milling Co., Salamanca, N. Y. "Choice distillers' grains, choice cottonseed meal, winter wheat bran, linseed meal, wheat middlings, corn gluten feed, corn meal, hominy, malt sprouts and 0.5 percent salt."

(9) *Farmers' Favorite Ration Feed*, City Feed Co., St. Albans, Vt., "Cottonseed meal, Buffalo gluten, malt sprouts, distillers' grains, bran and hominy or corn meal." Manufacturers offer a variant of this containing also "linseed meal and not over 0.75 percent salt."

(10) *Pontiac Dairy Ration*, R. H. McEwen Manufacturing Co., Ogdensburg, N. Y. "Distillers' dried grains, malt sprouts, hominy meal, cottonseed meal, linseed meal, wheat bran and 0.5 percent salt."

(11) *Dewey's Ready Ration*, Dewey Bros. Co., Blanchester, Ohio. "Eagle distillers' dried grains, old process oil meal, cottonseed meal, malt sprouts, wheat bran, wheat middlings, hominy feed and 0.5 percent salt."

(12) *Waumbeck Milk Makers' Mixture*, Mayflower Mills, Fort Wayne, Ind. "Dried malted grains, old process oil meal, cottonseed meal, pulverized grain screenings and 0.5 percent salt."

(13) *Union Grains*, Ubiko Milling Co., Cincinnati, Ohio. "Fourx distillers' dried grains, choice cottonseed meal, old process linseed meal, white wheat middlings, winter wheat bran, hominy meal, barley malt sprouts, 0.5 percent fine table salt."

(14) See 13.

(15) *Purina Cow Chow Feed*, Purina Mills Branch, Ralston Purina Co., St. Louis, Mo. "Cottonseed meal, hominy feed, brewers' dried grains, molasses, ground alfalfa and one percent salt."

(16) *Reavy's Dairy Feed*, Chittenden Mills, Jericho, Vt. "Cottonseed meal, linseed meal, gluten feed, distillers' or brewers' dried grains, wheat bran, wheat middlings, corn meal and a small quantity of salt."

(17) *Blue Ribbon Dairy Feed*, Quaker Oats Co., Chicago, Ill. "Hominy feed, malt sprouts, wheat bran, cottonseed meal, oat meal byproducts (oat middlings, oat hulls, oat shorts), linseed meal and molasses."

PROPRIETARY FEEDS (cont.)

Purina Mills, St. Louis, Mo.	Purina Dairy (19)	20.	22.8
Burlington Flouring Co., Burling- ton, Vt.	Perfection Dairy No. 3 (20) ..	22	20.9
Consolidated Milling Corporation.	Husted Justice Brand Dairy		
Buffalo, N. Y.	Scientific Ration (21)	20.	20.4
Purina Mills, St. Louis, Mo.	Purina Dairy (19)	20.	20.2
International Sugar Feed Co.,	International Special Dairy		
Minneapolis, Minn.	(22)	15.	20.2
Clover Leaf Milling Co., Buffalo, N. Y.	Peerless Dairy Ration (23) ...	21.	19.8
Clover Leaf Milling Co., Buffalo, N. Y.	Clover Leaf Dairy (24)	16.5	19.5
Chesbro Milling Co., Salamanca, N. Y.	Wheelock's Dairy (25)	18.	18.4
Western Grain Products Co., Hammond, Ind.	Hammond Dairy (26)	16.5	18.
American Milling Co., Peoria, Ill.	Sucrene Dairy (27)	16.5	18.
Postum Cereal Co., Battle Creek, Mich.	CXX (29)	15.	17.3
Western Grain Products Co., Hammond, Ind.	Hammond Dairy (26)	16.5	16.9
Western Grain Products Co., Hammond, Ind.	Hammond Dairy (26)	15.6	16.9
Quaker Oats Co., Chicago, Ill.	Quaker Molasses Dairy (30) ..	16.	16.9
Ralston Purina Co. Inc., Buffalo, N. Y.	Protena Dairy (31)	16.5	16.7
Clover Leaf Milling Co., Buffalo, N. Y.	Clover Leaf Dairy (24)	16.5	16.7
Western Grain Products Co., Hammond, Ind.	Hammond Dairy (26)	18.5	16.5
Western Grain Products Co., Hammond, Ind.	Hammond Horse (28)	12.	16.
Quaker Oats Co., Chicago, Ill.	Quaker Dairy (30)	16.	15.8
International Sugar Feed Co.,	International Special Dairy		
Minneapolis, Minn.	(22)	15.	15.4
International Sugar Feed Co.,	International Climax Dairy		
Minneapolis, Minn.	(31½)	12.5	12.4
Indiana Milling Co., Terre Haute, Ind.	Sterling (32)	9.8	12.3
North West Mills Co., Winona, Minn.	Sugarota Dairy (33)	16.5	11.8
Quaker Oats Co., Chicago, Ill.	Schumacher Stock (34)	10.	11.8
Purina Mills, St. Louis, Mo.	Purina Sweet (35)	10.3	11.4
Stratton & Co., Concord, N. H.	New Hampshire Stock (36) ..	10.	11.4
Corno Mills Co., St. Louis, Mo.	Corno Horse & Mule (37)	10.	11.4
Griswold & MacKinnon, St. Johns- bury, Vt.	Xtragood Stock (38)	10.	11.4
Chesbro Milling Co., Salamanca, N. Y.	Wheelock's Horse (39)	10.	10.9
Commercial Mills Co., St. Louis,	Alasco Sweet Meal (40)	10.	10.9
Elmore Mill Co., Oneonta, N. Y.	Elmore Stock (41)	10.	10.8
Quaker Oats Co., Chicago, Ill.	Schumacher Stock (34)	10.	10.8
Chas. M. Cox., Boston, Mass.	Wirthmore Stock (42)	9.	10.8
Purina Mills, St. Louis, Mo.	Purina Feed with Molasses		
	(43)	9.3	10.5
Chas. M. Cox Co., Boston, Mass.	Wirthmore Stock (42)	9.	10.5
Quaker Oats Co., Chicago, Ill.	Green Cross Horse Mixed		
	(44)	10.	10.3
Quaker Oats Co., Chicago, Ill.	Schumacher Special Horse		
	(45)	9.3	10.3

(18) *Elmore Milk Grains*, Elmore Milling Co., Oneonta, N. Y. "Corn distillers' dried grains, 41 percent cottonseed meal, old process linseed meal, corn gluten feed, hominy meal, choice wheat bran, barley, malt sprouts, dried brewers' grains, a little fine table salt."

(19) *Purina Dairy Feed*, Purina Mills Branch, Purina Co., St. Louis, Mo. "Cottonseed meal, brewers' dried grains, gluten feed meal, ground alfalfa, molasses and one percent salt."

(20) *Perfection Dairy Feed, No. 2*, Burlington Flouring Co., Burlington, Vt. "Cottonseed meal, old process linseed meal, hominy, gluten feed, dried beet pulp, brewers' dried grains, flour middlings and bran and 0.75 percent salt." Manufacturer has not been placing statement on packages, not being informed as to requirement of the law, but will do so hereafter.

(21) *Husted's Justice Brand Dairy Scientific Ration*, Consolidated Milling Corporation, Buffalo, N. Y. "Cottonseed meal, corn gluten feed, linseed oil meal, wheat middlings, corn distillers' dried grains, corn feed meal, clipped oat byproducts, malt sprouts or brewers' dried grains, molasses, 0.75 percent salt." (Illegal label in that "clipped oat byproducts" are not an ingredient but a combination of ingredients).

(22) *International Special Dairy Feed*, International Sugar Feed Co., Minneapolis, Minn. "Cottonseed, molasses, ground recleaned grain screenings, ground clipped oat byproducts, salt." (Illegal label in that "clipped oat byproducts" are not an ingredient but a combination of ingredients).

(23) *Peerless Dairy Ration*, Clover Leaf Milling Co., Buffalo, N. Y. "Cottonseed meal, wheat bran with screenings not exceeding mill run, distillers' grains, corn, gluten feed, clipped oat byproducts, molasses and a small percentage of salt." (Illegal label in that "clipped oat byproducts" are not an ingredient but a combination of ingredients).

(24) *Clover Leaf Dairy Feed*, Clover Leaf Milling Co., Buffalo, N. Y. "Cottonseed meal, corn gluten feed, mixed broken grains consisting of wheat, corn, barley, flax, speltz, ground grain screenings, clipped oat byproducts, molasses and a small percentage of salt." (Illegal label in that "clipped oat byproducts" are not an ingredient but a combination of ingredients).

(25) *Wheelock Dairy Feed*, Chesbro Milling Co., Inc., Salamanca, N. Y. "Corn meal, cottonseed meal, oil meal, corn gluten, wheat bran, distillers' grains, wheat middlings, chipped (*sic*) oat byproducts, molasses and 0.75 percent salt." (Illegal label in that "clipped oat byproducts" are not an ingredient but a combination of ingredients).

(26) *Hammond Dairy Feed*, Western Grain Products Co., Hammond, Ind. "Cottonseed meal, corn distillers' grains, malt sprouts, ground clipped oat byproducts, ground grain screenings, molasses and salt." (Illegal label in that "ground clipped oat byproducts" are not an ingredient but a combination of ingredients).

(27) *Sucrene Dairy Feed*, American Milling Co., Peoria, Ill. "Molasses, cottonseed meal, corn, gluten feed, ground and bolted grain screenings, clipped oat byproducts, linseed meal and salt." (Illegal label in that "clipped oat byproducts" are not an ingredient but a combination of ingredients).

(28) *Hammond Horse Feed*, Western Grain Products Co., Hammond, Ind. "Corn, oats, barley screenings, malt sprouts, linseed meal, molasses and 0.1 percent salt."

(29) *CXX Feed*, Postum Cereal Co., Ltd., Battle Creek, Mich. "Wheat, wheat bran and molasses, all treated. In process of manufacture molasses is nearly if not all eliminated." A variant of this reads "treated wheat, wheat bran and molasses."

(30) *Quaker Molasses Dairy Feed*, Quaker Oats Co., Chicago, Ill. "Cottonseed meal, malt sprouts, molasses, grain screenings, meal, oatmeal mill byproducts (oat middlings, oat hulls, oat shorts), and flax plant byproduct." The manufacturers furnish the following statement as to contents: "Molasses, malt sprouts, cottonseed meal, ground grain screenings, linseed meal, clipped oat byproduct." (Illegal label in that "clipped oat byproducts" are not an ingredient but a combination of ingredients).

(31) *Protene Dairy Feed*, Ralston Purina Co., Inc., Buffalo, N. Y. "Cottonseed meal, brewers' dried grains, clipped oat byproduct, ground wheat screenings, ground clipped oat byproducts, salt." (Illegal label in that "clipped oat byproducts" are not an ingredient but a combination of ingredients).

PROPRIETARY FEEDS (cont.)

Commercial Milling Co., Detroit, Mich.	Waumbeck Stable (46)	8.	10.1
Indiana Milling Co., Terre Haute, Ind.	Sterling (32)	10.	10.1
David Stott Flour Mills, Inc., De- troit, Mich.	Stott's Winner (47)	9.	10.1
Amendt-Milling Co., Monroe, Mich.	Amco Feed Meal (48)	8.5	9.9
Purina Mills, St. Louis, Mo.	XX Good with Molasses (49)	9.	9.6
Park & Pollard Co., Boston, Mass.	Park & Pollard Stock (50) ..	9.	9.6
J. H. Hewitt, So. Royaltown, Vt.	Our Stock (51)	8.	9.6
A. Waller & Co., Henderson, Ky.	Blue Grass (53)	9.	9.6
H. O. Co., Buffalo, N. Y.	De-F1 (53)	8.	9.6
Griswold & MacKinnon, St. Johnsbury, Vt.	Special Provender (54)	7.7	9.6
Commercial Milling Co., Detroit, Mich.	Henkel's Chop (55)	8.	9.4
Molassine Co., Boston, Mass.	Molassine Meal (56)	7.	9.2
Ralston Purina Co., St. Louis, Mo.	Purina Feed with Molasses (43)	9.	9.2
Globe Elevator Co., Buffalo, N. Y.	No. 1 Chop (57)	7.	9.
Quaker Oats Co., Chicago, Ill.	White Diamond (58)	8.	9.
Quaker Oats Co., Chicago, Ill.	White Diamond (58)	8.	8.3
Dow Cereal & Milling Co., Nee- pawa, Man.	Oat Feed (60)	..	5.3
Robin Hood Mills, Ltd., Moose Jaw, Sask.	Oat Feed (61)	5.3	6.1
Xtravim Molasses Feed Co., Boston, Mass.	Xtravim Molasses (59)	4.6	4.6
Xtravim Molasses Feed Co., Boston, Mass.	Xtravim Molasses (59)	4.6	4.8
Xtravim Molasses Feed Co., Boston, Mass.	Xtravim Molasses (59)	4.6	4.6
Xtravim Molasses Feed Co., Boston, Mass.	Xtravim Molasses (59)	4.6	4.6

HOMINY FEEDS

E. W. Bailey & Co., Montpelier, Vt.	..	12.7
Chas. M. Cox Co., Boston, Mass. Wirthmore	9.5	11.6
American Hominy Co., Indian- apolis, Ind. Homco	9.5	11.4
Quaker Oats Co., Chicago, Ill. Yellow	9.	11.4
Plymouth Milling Co., Lemars, Iowa Plymouth	10.	11.4
Chas. A. Krause Milling Co., Milwaukee, Wis. Badger	10.	11.2
Mystic Milling Co., Sioux City, Iowa	11.	11.2
Quaker Oats Co., Chicago, Ill. Yellow	9.	11.2
J. B. A. Kern & Sons, Milwaukee, Wis. Eagle	9.5	10.9
Eagle Roller Milling Co., New Ulm, Minn.	10.1	10.5

(31½) *International Climax Dairy Feed*, International Sugar Feed Co., Minneapolis, Minn. "Cottonseed meal, molasses, ground cleaned grain screenings, ground clipped oat byproducts, salt." (Illegal label in that "clipped oat byproducts" are not an ingredient but a combination of ingredients).

(32) *Sterling Feed*, Indiana Milling Co., Terre Haute, Ind. "Wheat bran, with ground screenings not exceeding mill run, ground corn, cob meal."

(33) *Sugarota Dairy Feed*, Northwest Mills Co., Winona, Minn. "Cottonseed meal, malt sprouts, mixed broken grains from screenings containing wheat, barley, oats, corn, speltz, flax, molasses and a small percent of salt."

(34) *Schumacher Stock Feed*, Quaker Oats Co., Chicago, Ill. "Ground corn, ground barley, hominy feed, wheat flour, wheat middlings, ground puffed rice, oatmeal mill byproducts (oat middlings, hulls, shorts), cottonseed meal, 0.5 percent salt."

(35) *Purina Sweet Feed*, Purina Mills Branch, Ralston Purina Co., St. Louis, Mo. "Ground alfalfa, ground grain screenings, molasses and one percent salt."

(36) *New Hampshire Stock Feed*, Stratton & Co., Concord, N. H. "Ground corn, oats, wheat and barley."

(37) *Corno Horse & Mule Feed*, Corno Mills Co., St. Louis, Mo. "Ground alfalfa, ground corn, cottonseed meal, hominy feed, oat feed." (Illegal label in that "oat feed" is not an ingredient but a mixture of ingredients).

(38) *Xtragood Stock Feed*, Griswold & MacKinnon, St. Johnsbury, Vt. "Ground corn, hominy feed, ground barley, wheat flour, wheat middlings with ground screenings not exceeding mill run, cottonseed meal, ground puffed rice, ground puffed wheat, oatmeal mill byproducts (oat middlings, oat hulls, oat shorts), and 0.5 percent salt."

(39) *Wheelock Horse Feed*, Chesbro Milling Co., Salamanca, N. Y. "Cracked corn, crushed oats, wheat, bran and molasses."

(40) *Alasco Sweet Meal*, Corno Mills Co., St. Louis, Mo. "Ground alfalfa and cane molasses."

(41) *Elmore Stock Feed*, Elmore Milling Co., Oneonta, N. Y. "Corn meal, hominy, dried brewers' grains, wheat bran, oatmeal mill byproducts (oat middlings, oat shorts, oat hulls)."

(42) *Wirthmore Stock Feed*, Charles M. Cox Co., Boston, Mass. "Ground barley, ground oats, ground hominy meal, ground corn and oatmeal with byproducts (oat middlings, oat shorts, and oat hulls)."

(43) *Purina Feed with Molasses*, Purina Mills Branch, Ralston Purina Co., St. Louis, Mo. "Cracked corn, whole oats, ground alfalfa, molasses and one percent salt."

(44) *Green Cross Horse Mixed Feed*, Quaker Oats Co., Chicago, Ill. "Alfalfa meal, ground corn, cracked oats, cottonseed meal, molasses, oatmeal mill byproducts (oat middlings, oat hulls, oat shorts)."

(45) *Schumacher Special Horse Feed*, Quaker Oats Co., Chicago, Ill. "Ground corn, cracked oats, oatmeal mill byproducts (oat middlings, oat hulls, oat shorts), and 0.5 percent salt."

(46) *Waumbeck Stable Feed*, Commercial Milling Co., Detroit, Mich. "Corn meal, wheat and oat middlings, oats and oat hulls."

(47) *Stott's Winner Feed*, David Stott Flour Mills, Inc., Detroit, Mich. "Corn meal, oats, screenings, oat hulls and salt."

(48) *Amco Feed Meal*, Amendt Milling Co., Monroe, Mich. "Siftings from manufacture of table corn meal and siftings from manufacture of cracked corn."

(49) *XX Good Feed with Molasses*, Purina Mills Branch, Ralston Purina Co., St. Louis, Mo. "Cracked corn, whole oats, ground grain screenings, ground alfalfa, molasses and one percent salt."

(50) *Park and Pollard Stock Feed*, Park and Pollard Co., Boston, Mass. "Ground corn, hominy feed and oat feed." (Illegal label in that "oat feed" is not an ingredient but a combination of ingredients).

(51) *Our Stock Feed*, J. H. Hewitt, South Royalton, Vt. "No label. Manufacturer promises to comply with law."

(52) *Blue Grass Feed*, A. Waller, Henderson, Ky. "Winter wheat bran, winter wheat middlings, ground corn and cob."

PROVENDER

E. W. Bailey & Co., Montpelier, Vt.	11.4
A. G. Spaulding, Ludlow, Vt.	10.3
Mrs. E. H. Atherton, Cavendish, Vt.	10.1
Davis Feed Co., Rutland, Vt.	10.1
Ogdensburg Roller Mills, Og- densburg, N. Y.	10.1
J. H. Hewitt, So. Royalton, Vt.	10.1
Tioga Mill & Elevator Co., Waver- ly, N. Y.	10.1
Burditt Bros., Rutland, Vt.	9.9

CORN MEAL

Tioga Mill & Elevator Co., Waver- ly, N. Y.	Derby ¹ ..	10.1
Mrs. E. H. Atherton, Cavendish, Vt.	..	9.2
E. W. Bailey & Co., Montpelier, Vt.	..	9.2
Burditt Bros., Rutland, Vt.	..	9.2
E. Crosby & Co., Brattleboro, Vt.	..	9.2
Davis Feed Co., Rutland, Vt.	..	8.8
A. G. Spaulding, Ludlow, Vt.	..	8.6
Thompson Mill Co., Lockport, N. Y.	..	8.3
R. H. McEwen Milling Co., Og- densburg, N. Y.	..	7.7

DRIED BEET PULP

Chas. Pope, Chicago, Ill.	8.	9.
Michigan Sugar Co., Saginaw, Mich.	8.	8.8
Larrowe Milling Co., Detroit, Mich.	8.	8.8
Larrowe Milling Co., Detroit, Mich.	8.	8.8

ALFALFA MEAL

Somers & Co.	Red Star ..	16.6	19.1
Jos. Breck & Son, Boston, Mass.	Cut ..	12.	15.8
Jos. Breck & Son, Boston, Mass.	..	12.	15.7
Berkshire Coal & Grain Co., North Adams, Mass.	..	..	14.5
M. C. Peters Milling Co., Omaha, Neb.	Lucern Pure ..	12.	13.5
Albert Dickinson & Co., Chicago, Ill.	..	12.	13.
Albert Dickinson & Co., Chicago, Ill.	..	12.	12.3
Park & Pollard Co., Boston, Mass.	P. & P.	12.	12.1

¹Ground corn with a percentage of cracked corn removed.

(53) *De-Ft Feed*, H. O. Company, Buffalo, N. Y. "Oat hulls, oat shorts, ground corn, hominy feed, wheat middlings, oat middlings, ground grain screenings, molasses and 0.5 per cent salt."

(54) *Special Provender*, Griswold and MacKinnon, St. Johnsbury, Vt. "Corn, hominy and oat hulls."

(55) *Henkel's Chop Feed*, Commercial Milling Co., Detroit, Mich. "Corn meal, rye and oat midds, oat and oat hulls."

(56) *Molassine Meal*, The Molassine Co., Boston, Mass. "Molasses and cooked sphagnum."

(57) *No. 1 Chop Feed*, Globe Elevator Co., Buffalo, N. Y. "Ground corn and oats and oat hulls, flour middlings and 0.5 percent salt."

(58) *White Diamond Feed*, Quaker Oats Co., Chicago, Ill. "Ground corn, hominy, feed, oatmeal mill byproducts (oat middlings, oat hulls, oat shorts) and 0.5 percent salt."

(59) *Xtravim Molasses Feed*, Xtravim Molasses Feed Co., Boston, Mass. "Pure cane sugar molasses, mixed with a small percentage of sphagnum moss."

(60) Ingredients not stated.

(61) *Oat Feed*, Robin Hood Mills, Ltd., Moose Jaw, Sask. No descriptive label. (Illegal).

(62) *Ryde's Cream Calf Meal*, Ryde & Co., Chicago, Ill. "Fenugreek, anise seed, cottonseed meal, wheat flour, flaxseed meal, carob beans, bean meal, lentils, cocoa shells, and salt."

(63) *Blatchford's Calf Meal*, Blatchford's Calf Meal Factory, Waukegan, Ill. "Locust bean meal, unpressed flaxseed, wheat flour, barley meal, ground beans and peas, rice polish, old process oil meal, cocoa shell meal, cocoanut meal, re-cleaned cottonseed meal, fenugreek, dried milk, anise and salt."

(64) *Blatchford's Pig Meal*, Blatchford's Calf Meal Factory, Waukegan, Ill. "Linseed oil meals, oat meals, wheat flour, corn meals, rice polish, barley meals, re-cleaned cottonseed meal, cocoa shell meal, bean meal, crushed flaxseed, fenugreek, salt."

(65) *Schumacher's Calf Meal*, Quaker Oats Co., Chicago, Ill. "Oatmeal, wheat meal, dried casein, ground flaxseed, cottonseed meal, and not to exceed 0.5 percent bicarbonate of soda."

(66) *Lowell Bone and Meat Meal*, Lowell Fertilizer Co., Boston, Mass. "Bone and meat meal."

(67) *Ground Beef Scraps*, Jos. Breck & Sons, Boston, Mass. "Ground beef scraps."

Hominy meal, hominy feed, or hominy chop is a mixture of the bran coating, the germ and a part of the starchy portion of the corn kernel obtained in the manufacture of hominy grits for human consumption.

Corn and oat feeds are proprietary mixtures into the compounding of which enter considerable quantities of oat byproducts as well as corn. They usually carry less than 12 percent protein and from 8 percent upwards of crude fiber. "Chop" is a ground or chop feed composed of one or more different cereals or the byproducts therefrom.

Alfalfa meal is the entire alfalfa hay ground, and does not contain an admixture of ground alfalfa straw or other foreign materials.

Dried beet pulp is the dried sugar beet residue obtained in the manufacture of beet sugar, with or without an admixture of beet molasses.

CALF MEALS

Ryde & Co., Chicago, Ill.	Ryde's Cream Calf Meal (62) .	25.	26.8
Ryde & Co., Chicago, Ill.	Ryde's Cream Calf Meal (62) .	26.	26.3
Blatchford's Calf Meal Factory, Waukegan, Ill.	Blatchford's Calf Meal (63) ..	24.	26.2
Blatchford's Calf Meal Factory, Waukegan, Ill.	Blatchford's Calf Meal (63) ..	24.	25.2
Blatchford's Calf Meal Factory, Waukegan, Ill.	Blatchford's Pig Meal (64) ..	18.	19.8
Quaker Oats Co., Chicago, Ill.	Schumacher's Calf Meal (65) .	19.	18.7
Quaker Oats Co., Chicago, Ill.	Schumacher's Calf Meal (65) .	19.	18.2

OATS AND RYE FEED

E. W. Bailey & Co., Montpelier, Vt.	Ground Oats ..	12.7	
Burditt Bros., Rutland, Vt.	Ground Oats ..	12.3	
Eagle Roller Mill Co., New Ulm, Minn.	Rye Feed ..	17.4	18.4
Boutwell Milling & Grain Co., Troy, N. Y.	Rye Feed ..	13.5	14.7

POULTRY FEEDS

ANIMAL MEAL, MEAT SCRAPS, GROUND BONE

Lowell Fertilizer Co., Boston, Mass.	Lowell Bone and Meat Meal (66) ..	35.	52.2
Lowell Fertilizer Co., Boston, Mass.	Lowell Bone and Meat Meal (66) ..	35.	52.1
Jos. Breck & Sons, Boston, Mass.	Ground Beef Scraps (67) ..	43.	46.1
John C. Dow & Co., Boston, Mass.	Ground Beef Scraps (67½) ..	43.	46.1
Manchester Rendering Co., Manchester, N. H.	Bone and Meat Meal (68)	35.	44.8
Burlington Rendering Co., Burlington, Vt.	Burlington Poultry Food (69) ..	40.	42.9
C. M. Shay Fertilizer Co., Groton, Conn.	Shay's Beef Scraps (70) ..	40.	40.8
Burlington Rendering Co., Burlington, Vt.	Burlington Poultry Food (69) ..	40.	40.
Burlington Rendering Co., Burlington, Vt.	Cracked Bone for Poultry (71) ..	20.	26.1
Jos. Breck & Sons, Boston, Mass.	Bone Meal for Cattle (72) ...	12.	13.4
Beach Soap Co., Lawrence, Mass.	Bone Meal (73) ..	10.	11.4

POULTRY MASHES

Chas. M. Cox Co., Boston, Mass.	Wirthmore, Dry, All Grain		
Berkshire Coal & Grain Co., North Adams, Mass.	(74) ..	17.	23.6
J. H. Hewitt, South Royalton, Vt.	Maine (75) ..	10.	23.4
Vt.	Our Dry (76) ..	..	23.
Park & Pollard Co., Boston, Mass.	Lay or Bust, Dry (77) ..	18.	22.4
Park & Pollard Co., Boston, Mass.	Lay or Bust, Dry (77) ..	18.	21.3
Blatchford's Calf Meal Factory, Waukegan, Ill.	Blatchford (78) ..	19.	20.6
Ralston Purina Co., St. Louis, Mo.	Purina Chicken Chowder (79) ..	17.	20.4
N. W. Morse & Sons, Randolph, Vt.	Home Mixed, Dry (80) ..	18.	20.4

(67½) *Dow's Beef Scraps*, John C. Dow Co., Boston, Mass. "Beef scraps."

(68) *Bone and Meat Meal*, Manchester Rendering Co., Manchester, N. H. "Cooked meat and bone scraps."

(69) *Burlington Poultry Feed*, Burlington Rendering Co., Burlington, Vt. "Cooked meat and bone scraps."

(70) *Shay's Beef Scraps*, C. M. Shay Fertilizer Co., Groton, Conn. "Bone and meat meal."

(71) *Cracked Bone for Poultry*, Burlington Rendering Co., Burlington, Vt. "Cracked bone."

(72) *Bone Meal for Cattle*, Jos. Breck & Sons, Boston, Mass. "Bone meal."

(73) *Bone Meal*, Beach Soap Co., Lawrence, Mass. "Bone meal."

(74) *Wirthmore Poultry Mash (All Grain)*, Chas. M. Cox Co., Boston, Mass. "Ground oats, ground barley, gluten feed, alfalfa meal, wheat bran, ground corn, wheat middlings and about 0.75 percent salt."

(75) Ingredients not stated. See 113.

(76) *Our Dry Mash*, J. H. Hewitt, South Royalton, Vt. "Corn meal, gluten, wheat middlings, wheat bran, linseed meal, alfalfa meal and beef scraps."

(77) *Lay or Bust Dry Mash*, Park & Pollard Co., Boston, Mass. "Wheat bran, wheat middlings, corn, wheat, oats, barley, Kaffir corn, buckwheat, alfalfa, fish, meat, bone, beet pulp, calcium carbonate and salt."

(78) *Blatchford's Milk Mash*, Blatchford's Calf Meal Factory, Waukegan, Ill. "Bean, cocoanut, cottonseed, flaxseed, locust bean, linseed oil and pea meals, fenugreek, wheat flour, dried milk, cocoa shells, salt, alfalfa, barley, bone, corn and oat meals, wheat bran, wheat middlings, beef scraps, fish, capsicum and limestone grit."

(79) *Purina Chicken Chowder Feed*, Purina Mills Branch, Ralston Purina Co., St. Louis, Mo. "Wheat middlings, wheat bran, corn meal, alfalfa meal, linseed meal, granulated meat, not over one percent salt."

(80) *Home Mixed Dry Mash*, N. N. Morse & Sons, Randolph, Vt. "Corn meal, bran, ground oats, wheat middlings, alfalfa meal, beef scraps, fish scraps, linseed meal, charcoal, salt."

Calf meals are proprietary feeds intended as whole or partial substitutes for milk in the feeding of young calves.

Meat scrap and meat meal are the ground residues from animal tissue exclusive of hoof and bone. If they contain any considerable amount of bone, they must be designated meal and bone scrap, or meat and bone meal. If they bear a name descriptive of their kind, composition or origin, they must correspond thereto.

Rye feeds are byproducts obtained in the manufacture of rye flour.

POULTRY MASHES (cont.)

Purina Mills, St. Louis, Mo.....	Purina Chicken Chowder (79)	17.	19.9
Quaker Oats Co., Chicago, Ill....	Quaker (81)	17.5	19.9
Quaker Oats Co., Chicago, Ill....	Quaker (81)	17.5	19.9
Chas. M. Cox Co., Boston, Mass...	Wirthmore (74)	17.	19.8
Burditt Bros., Rutland, Vt.....	B. B. Dry (82)	14.	19.6
Blatchford's Calf Meal Factory, Waukegan, Ill.	Fill the Basket Egg (83)	19.	19.5
Park & Pollard Co., Boston, Mass.	Lay or Bust, Dry (77)	18.	19.5
Chas. M. Cox Co., Boston, Mass...	Wirthmore (with fish and scraps) (84)	17.	18.6
Chas. M. Cox Co., Boston, Mass...	Wirthmore, Dry, All Grain (74)	17.	18.
A. B. Kilbourne, Bristol, Vt.....	Dry (85)	16.	17.1
Albert Dickinson Co., Chicago, Ill.	Queen (86)	11.	11.2

SCRATCH FEEDS

Purina Mills, St. Louis, Mo.....	Purina (87)	11.	12.1
American Milling Co., Peoria, Ill.	Cluck-Cluck (88)	10.	11.8
Buffalo Cereal Co., Buffalo, N. Y.	Iroquois (89)	10.	11.6
Park & Pollard Co., Boston, Mass.	Red Ribbon (90)	10.	11.6
Quaker Oats Co., Chicago, Ill....	Schumacher (91)	10.	11.6
Stratton & Co., Concord, N. H. (92)		10.	11.4
Albert Dickinson Co., Chicago, Ill.	Globe (93)	10.	11.4
Park & Pollard Co., Boston, Mass.	P. & P. (94)	10.	11.2
Chas. M. Cox Co., Boston, Mass...	Wirthmore (95)	11.	11.2
Purina Mills, St. Louis, Mo.....	Purina (87)	11.	10.9
Albert Dickinson Co., Chicago, Ill.	Globe (93)	10.	10.9
E. T. & H. K. Ide, St. Johnsbury, Vt.	Ideal No. 2 (96)	10.	10.9
Griswold & MacKinnon, St. Johnsbury, Vt.	Xtragood (97)	11.	10.9
Amendt Milling Co., Monroe, Mich.	Amco (98)	10.	10.9
Amendt Milling Co., Monroe, Mich.	Amco (98)	10.	10.9
Quaker Oats Co., Chicago, Ill....	Schumacher (91)	10.	10.9
Griswold & MacKinnon, St. Johnsbury, Vt.	Xtragood (97)	10.	10.8
Park & Pollard Co., Boston, Mass.	Screened (99)	10.	10.8
A. B. Kilbourne, Bristol, Vt.	(100)	10.	10.8
Park & Pollard Co., Boston, Mass.	Red Ribbon (90)	10.	10.3
Park & Pollard Co., Boston, Mass.	P. & P. (94)	10.	10.3

(81) *Quaker Poultry Mash*, Quaker Oats Co., Chicago, Ill. "Meat scraps, oat meal, wheat bran, alfalfa meal, yellow hominy feed, gluten feed, ground grain screenings."

(82) *B. B. Dry Mash*, Burditt Bros., Rutland, Vt. "Alfalfa, bran, midds, meal, gluten, oil meal, meat scraps, Hen-eta." (Illegal label in that the word "meal" is not accurately descriptive and that "Hen-eta" is a proprietary product and not an "ingredient").

(83) *Blatchford's Fill the Basket Egg Meal Mash*, Blatchford's Calf Meal Factory, Waukegan, Ill. "Bean, cocoanut, cottonseed, flaxseed, locust bean, linseed oil and pea meals, fenugreek, wheat flour, dried milk, cocoa shells, salt, alfalfa, barley, bone, corn and oat meals, wheat bran, wheat middlings, beef scraps, fish, capsicum and limestone grit."

(84) *Wirthmore Poultry Mash (Fish and Scraps)*, Chas. M. Cox Co., Boston, Mass. "Ground oats, ground barley, gluten feed, alfalfa meal, wheat bran, ground corn, choice fine ground beef scraps, fish meal, wheat middlings and about 0.75 percent salt."

(85) *Dry Mash*, A. B. Kilbourne, Bristol, Vt. "Alfalfa meal, corn meal, ground oats, wheat bran, wheat middlings, gluten feed, linseed oil meal, meat scraps."

(86) *Queen Poultry Mash*, Albert Dickinson Co., Chicago, Ill. "Alfalfa meal, corn feed meal, wheat meal, ground corn bran, wheat bran, meat scraps, linseed oil cake and 0.5 percent salt."

(87) *Purina Scratch Feed*, Purina Mills Branch, Ralston Purina Co., St. Louis, Mo. "Wheat corn, barley, Kaffir corn, milo maize, sunflower."

(88) *Cluck Cluck Scratch Feed*, American Milling Co., Peoria, Ill. "Corn, wheat, barley, Kaffir corn, sunflower seed and buckwheat."

(89) *Iroquois Scratching Grains*, Buffalo Cereal Co., Buffalo, N. Y. "Corn, oats, barley, buckwheat, Kaffir corn, wheat, sunflower seed."

(90) *Red Ribbon Scratch Feed*, Park & Pollard Co., Boston, Mass. "Cracked corn, wheat, buckwheat, barley, Kaffir corn, oats, milo, sunflower seed."

(91) *Schumacher Scratching Grains*, Quaker Oats Co., Chicago, Ill. "Whole wheat, whole Kaffir corn, whole barley, cracked Indian corn, whole buckwheat, sunflower seeds."

(92) *Stratton & Co.'s Scratch Feed*, Stratton & Co., Concord, N. H. "Corn, wheat, rye, barley, oats, buckwheat, Kaffir corn, sunflower and oil cake."

(93) *Globe Scratch Feed*, Albert Dickinson Co., Chicago, Ill. "Corn, wheat, barley, oats, Kaffir corn, buckwheat, sunflower, oil cake."

(94) *Screened Scratch Feed*, Park & Pollard Co., Boston, Mass. "Cracked corn, wheat, Kaffir corn, barley, buckwheat, oats, peas, sunflower seed."

(95) *Wirthmore Scratch Feed*, Charles M. Cox Co., Boston, Mass. "Sunflower seed, wheat, oats, buckwheat, barley, milo maize and cracked corn." Manufacturers give two variants of this; one in which sunflower seed is replaced by Kaffir corn and one denominated "S." in which Kaffir corn is added to the list.

(96) *Ideal Scratch Feed No. 2*, E. T. & H. K. Ide, St. Johnsbury, Vt. "Corn, wheat, Kaffir corn, oats, India wheat, sunflower seed."

(97) *Xtragood Scratch Feed*, Griswold & MacKinnon, St. Johnsbury, Vt. "Wheat, Kaffir corn, barley, oats, cracked corn, buckwheat, milo maize and sunflower seed."

(98) *Amco Scratch Grains*, Amendt Milling Co., Monroe, Mich. "Wheat, wheat screenings, cracked corn, Kaffir corn or milo maize, barley, buckwheat, corn germ, linseed oil cake, meat scraps, charcoal, shell and grit."

(99) *Screened Scratch Feed*, Park & Pollard Co., Boston, Mass. "Cracked corn, wheat, buckwheat, barley, oats, Kaffir corn, milo and sunflower seed."

(100) *Scratch Feed*, A. B. Kilbourne, Bristol, Vt. "Cracked corn, oats, barley, wheat, buckwheat, Kaffir corn, sunflower seed, charcoal."

CHICK FEEDS, GROWING FEEDS ETC.

Park & Pollard Co., Boston, Mass.	Growing Feed (101)	10.	16.5
Park & Pollard Co., Boston, Mass.	Growing Feed (101)	10.	15.4
Park & Pollard Co., Boston, Mass.	Margaret Mahaney's Turkey Feed (102)	10.	14.3
Park & Pollard Co., Boston, Mass.	Gritless Chick Feed (103)	11.	13.6
Robin Hood Mills Ltd., Moose, Jaw, Man.	Shelled Oats (104)	..	13.4
Chas. M. Cox Co., Boston, Mass.	Wirthmore Chick (105)	11.	12.3
Chas. M. Cox Co., Boston, Mass.	Wirthmore Growing, All Grain (106)	12.	12.3
Buffalo Cereal Co., Buffalo, N. Y.	Bufceco Chick (107)	12.	12.3
Buffalo Cereal Co., Buffalo, N. Y.	Bufceco Chick (107)	12.	11.7
Corno Mills Co., St. Louis, Mo.	Corno Hen (108)	10.	11.6
Park & Pollard Co., Boston, Mass.	Gritless Chick (103)	11.	11.6
Quaker Oats Co., Chicago, Ill.	Quaker Chick (109)	10.	11.4
Chas. M. Cox Co., Boston, Mass.	Wirthmore Gritless Chick (110)	10.	11.4
Park & Pollard Co., Boston, Mass.	Intermediate Chick (111)	10.	11.4
Park & Pollard Co., Boston, Mass.	Red Ribbon Chick (112)	10.	11.4
Berkshire Coal & Grain Co., North Adams, Mass.	Berkshire Chick (113)	10.	11.2
Quaker Oats Co., Chicago, Ill.	Quaker Chick (114)	10.	11.2
Quaker Oats Co., Chicago, Ill.	Little Chick (115)	10.	10.8
E. Crosby & Co., Brattleboro, Vt.	Crosby's Chick (116)	10.	10.8
Corno Mills Co., St. Louis, Mo.	Corno Chick (117)	10.8	10.5
Park & Pollard Co., Boston, Mass.	Fattening Feed (118)	10.	9.6

(101) *Growing Feed*, Park & Pollard Co., Boston, Mass. "Ground corn, wheat, barley, oats, meat, bone, alfalfa, Kaffir corn, wheat bran, wheat middlings, buckwheat, beet pulp, calcium carbonate and salt."

(102) *Margaret Mahaney's Turkey Feed*, Park & Pollard Co., Boston, Mass. "Ground wheat, barley, linseed oil meal, oats, meat, bone, calcium hydroxide, calcium carbonate and salt."

(103) *Gritless Chick Feed*, Park & Pollard Co., Boston, Mass. "Cracked corn, cracked wheat, cracked Kaffir corn, cracked milo, whole millet seed and shredded fish."

(104) Ingredients not stated.

(105) *Wirthmore Chick Feed*, Charles M. Cox Co., Boston, Mass. "Cracked milo maize, cracked yellow corn, cracked white corn, cracked wheat, hulled oats, peas." The manufacturers furnish a combination differing from this by the inclusion of Kaffir corn."

(106) *Wirthmore Growing Feed (All Grain)*, Charles M. Cox Co., Boston, Mass. "Ground wheat, corn, oats, barley, peas, milo maize, buckwheat, wheat middlings and salt."

(107) *Bufceco Chick Feed*, Buffalo Cereal Co., Buffalo, N. Y. "Corn, wheat, Kaffir corn, peas, millet and oat groats."

(108) *Corno Hen Feed*, Corno Mills Co., St. Louis, Mo. "Wheat, corn, wheat screenings, Kaffir corn or milo maize."

(109) *Quaker Chick Feed*, Quaker Oats Co., Chicago, Ill. "Cracked wheat, cracked Kaffir corn, cracked Indian corn, whole millet seed, oatmeal, wild buckwheat, with not to exceed 0.5 percent miscellaneous wild seeds occurring in above seeds and grains, and marble grit."

(110) *Wirthmore Gritless Chick Feed*, C. M. Cox Co., Boston, Mass. "Cracked wheat, yellow corn, peas, Kaffir corn, milo maize, white corn and hulled oats."

(111) *Intermediate Chick Feed*, Park & Pollard Co., Boston, Mass. "Cracked corn, wheat, buckwheat, oats, millet, Kaffir corn and milo."

(112) *Red Ribbon Chick Feed*, Park & Pollard Co., Boston, Mass. "Cracked corn, cracked wheat, cracked oats, Kaffir corn, and whole millet seed."

(113) *Berkshire Chick Feed*, Berkshire Coal & Grain Co., North Adams, Mass. Ingredients not stated. Manufacturers state that the goods are made for them by the Quaker Oats Co., and that they understand their composition and ingredients to be identical with the Quaker Chick Feed (No. 114, which see). Manufacturers promise to comply with the law hereafter.

(114) *Quaker Chick Feed*, Quaker Oats Co., Chicago, Ill. "Cracked wheat, cracked Kaffir corn, cracked Indian corn, whole millet seeds, oatmeal, charcoal, marble grit, wild buckwheat (with not to exceed 0.5 percent of miscellaneous wild seeds occurring in above seeds and grains)."

(115) *Quaker Little Chick Feed*, Quaker Oats Co., Chicago, Ill. "Cracked wheat, cracked Kaffir corn, cracked Indian corn, whole millet seeds, oatmeal, charcoal, marble grit, wild buckwheat (with not to exceed 0.5 percent of miscellaneous wild seeds occurring in above seeds and grains)."

(116) *Crosby's Chick Feed*, E. Crosby & Co., Brattleboro, Vt. "Corn, wheat, Kaffir corn, hulled oats, millet—contains no grit."

(117) *Corno Chick Feed*, Corno Mills Co., St. Louis, Mo. "Wheat, corn, wheat screenings, Kaffir corn, millet seed."

(118) *Fattening Feed*, Park & Pollard Co., Boston, Mass. "Ground corn, wheat, barley, Kaffir corn, oats and salt."

WHEAT BRAN

Western Star Milling Co., Salina, Kans.	Star (3)	15.	19.8
Stanard-Tilton Milling Co., St. Louis, Mo.	(5)	14.5	18.4
Western Canada Flour Milling Co., Ltd.	Western Canada	16.8	18.
Kempton Milling & Elevator Co., Kansas City, Mo.	Anchor (1)	14.5	17.8
Hunter-Robinson-Wenz Milling Co., St. Louis, Mo.	(1)	15.5	17.6
Kehler Flour Mill Co., St. Louis, Mo.	Palace	14.5	17.6
Larabee Flour Mills Co., Hutch- inson, Kans.	(4)	14.5	17.6
Williamson Mill Co., Clay Center, Kans. ....	.....	15.5	17.6
Russell-Miller Milling Co., Min- neapolis, Minn. ....	.....	13.	17.5
Red River Milling Co., Fergus Falls, Minn. ....	.....	15.6	17.3
Federal Milling Co., Lockport, N. Y.	Lucky	15.	17.3
Cain Milling Co., Atchison, Kan. Cain's .....	.....	14.3	17.1
Hunter-Robinson-Wenz Milling Co., St. Louis, Mo.	Winter	14.5	17.1
New Prague Flouring Mill Co., New Prague, Minn.	Seal of Minnesota	14.6	17.1
Western Flour Mill Co., Daven- port, Iowa	Blackhawk	14.6	17.3
L. G. Campbell Milling Co., Owatonna, Minn.	Choice	13.4	16.9
Commercial Milling Co., Detroit, Mich. ....	.....	14.	16.9
Niagara Falls Milling Co., Niagara Falls, N. Y.	Niagara Falls	14.	16.9
Thompson Milling Co., Lockport, N. Y.	Angelus	15.	16.7
Star & Crescent Milling Co., Chi- cago, Ill.	Star	15.	16.7
Northwestern Consolidated Mill- ing Co., Minneapolis, Minn.	Pure	14.5	16.7
Niagara Falls Milling Co., Niagara Falls, N. Y.	Choice	14.	16.7
Maple Leaf Milling Co., Toronto, Ont.	Maple Leaf	15.5	16.7
B. A. Eckhart Milling Co., Chi- cago, Ill.	(1)	14.	16.7
David Stott Flour Mills, Detroit, Mich.	Stott's (1)	16.	16.5
Detroit Milling Co., Detroit, Mich.	Adrain	15.	16.4
Valley City Milling Co., Grand Rapids, Mich.	Farmers' Favorite	14.7	16.4
Washburn Mills, Minneapolis, Minn.	Washburn-Crosby's	14.5	16.4
Pillsbury Co., Minneapolis, Minn. Pillsbury's (1) .....	.....	14.5	16.4
Barber Milling Co., Minneapolis, Minn.	Star	14.	16.4

¹"With ground screenings not exceeding mill run."

²"And screenings."

³"With mill run screenings not to exceed 8 percent."

⁴"With screenings not exceeding mill run."

WHEAT BRAN (cont.)

Anstead & Burke Co., Springfield, Ohio	(1)	13.	16.3
Chas. M. Cox Co., Boston, Mass. Monogram (1)		15.	16.3
Duluth-Superior Milling Co., Du- luth, Minn.	Duluth Imperial	15.	16.3
Ogdensburg Roller Mills Co., Og- densburg, N. Y.	Ogdensburg Choice	14.	16.3
F. W. Stock & Sons, Hillsdale, Mich.		14.	16.3
Gwinn Milling Co., Columbus, Ohio	Gwinn's	15.	15.8
Claro Milling Co., Lakeville, Minn.	Claro	14.	15.8
Bill, Bell & Co., Ogdensburg, N. Y.		14.3	15.8
Hecker-Jones-Jewell Milling Co., Buffalo, N. Y.	Choice (2)	15.8	15.7
David Stott Flour Mills, Detroit, Mich.	Stott's	16.	15.5
J. G. Davis Co., Rochester, N. Y. Granite Choice		14.	15.5
Geo. C. Christian, Minneapolis, Minn.	Jersey	13.	15.4
Wm. A. Coombs Milling Co., Coldwater, Mich.	(1)	14.	15.4
Mystic Milling Co., Sioux City, Minn.	Mystic	14.	15.4
Red Wing Milling Co., Red Wing, Minn.	Bixota	15.	15.4
Chippewa Milling Co., Minne- apolis, Minn.	Chippewa	13.9	15.4
National Milling Co., Toledo, O.		16.5	15.1
Voight Manufacturing Co., Grand Rapids, Mich.	Voight's Pure	17.	14.8
Red Wing Milling Co., Red Wing, Minn.	Bixota	13.9	14.8

WHEAT MIDDINGS

Barber Mill Co., Minneapolis, Minn.	Fancy White	17.	19.9
Barber Mill Co., Minneapolis, Minn.	Barber	14.	19.4
Pillsbury Co., Minneapolis, Minn. XX Dalsey		17.	19.3
Hecker-Jones-Jewell Milling Co., Buffalo, N. Y.	Standard (1)	17.4	19.1
Washburn Mills, Minneapolis, Minn.		17.	18.9
Russell-Miller Milling Co., Min- neapolis, Minn.	Standard	15.	19.
L. Christian & Co.	Standard	15.5	18.6
Crescent Milling Co., Fairfax, Minn.	Crescent	16.2	18.6
Hecker-Jones-Jewell Milling Co., Buffalo, N. Y.	Standard (1)	17.4	18.4
Thompson Milling Co., Lockport, N. Y.	Angelus Flour	18.5	18.3
Pillsbury Co., Minneapolis, Minn.	Standard A	15.	18.3

"With ground screenings not exceeding mill run."

"With trace of screenings."

WHEAT MIDDINGS (cont.)

Tioga Mill & Elevator Co., Waverly, N. Y.	Waverly Flour (2)	16.	18.2
Atlas Flour Mills, Milwaukee, Wis.	Atlas	16.	18.2
Anstead & Burke Co., Springfield, Ohio	Wheat (1)	14.	18.
Bill, Bell & Co., Ogdensburg, N. Y.	Flour	16.5	18.
Niagara Falls Milling Co., Niagara, N. Y.	Choice Wheat	16.	18.
Atlas Flour Mills, Milwaukee, Wis.	Atlas Flour (1)	14.	17.9
Chas. M. Cox Co., Boston, Mass.	Wirthmore (3)	15.	17.8
National Milling Co., Toledo, Ohio	Wheat	17.5	17.8
Washburn Mills, Minneapolis, Minn.	Standard	15.3	17.8
Washburn Mills, Minneapolis, Minn.	Standard	15.	17.6
Tennant & Hoyt Co., Lake City, Minn. ....	.....	16.	17.6
David Stott Flour Mills, Detroit, Mich.	Climax	17.	17.6
David Stott Flour Mills, Detroit, Mich.	Pennant	17.	17.6
Russell-Miller Milling Co., Minneapolis, Minn.	Russell-Miller	17.	17.6
Lidgerwood Milling Co., Lidgerwood, No. Dak.	Pure Wheat	16.5	17.6
C. S. Christensen Co., Madelia, Minn.	Madelia (1)	14.3	17.6
Big Diamond Mills Co., Minneapolis, Minn.	Big Diamond	14.7	17.6
Bill, Bell & Co., Ogdensburg, N. Y.	Shorts	16.	17.3
Thornton & Chester Milling Co., Buffalo, N. Y.	T. & C. Wheat	15.	17.3
Commercial Milling Co., Detroit, Mich.	Standard (4)	16.	17.1
Detroit Milling Co., Detroit, Mich.	Apex Winter	17.	17.1
Red Wing Milling Co., Red Wing, Minn.	Bixota	18.3	17.
Marshall Milling Co., Marshall, Minn.	Shorts	17.	16.8
F. W. Stock & Sons, Hinsdale, Mich. ....	.....	16.	16.7
David Stott Flour Mills, Detroit, Mich.	Fine White	18.	16.7
Federal Milling Co., Lockport, N. Y.	Dairy Maid Winter (1)	16.	16.4
Pillsbury Co., Minneapolis, Minn.	Standard B	15.	15.8
Valley City Milling Co., Grand Rapids, Mich.	Farmers' Favorite	15.5	15.8
Voight Milling Co., Grand Rapids, Mich.	Voight's	14.5	15.4
Commercial Milling Co., Detroit, Mich.	Fine	15.	15.4

"With ground screenings not exceeding mill run."

"May contain ground screenings not exceeding mill run."

"And red dog flour."

"With ground screenings."

WHEAT MIXED FEEDS

Sparks Milling Co., Alton, Ill...Try Me	16.	18.9
Northwestern Consolidated Milling Co., Minneapolis, Minn....Flame	15.	18.9
Northwestern Consolidated Milling Co., Minneapolis, Minn....Pequot	15.	18.4
Kemper Milling & Elevator Co., Kansas City, Mo. ....Anchor	16.	18.2
Geo. E. Dean, Rochester, N. Y...Dean's (2)	16.	18.2
Pillsbury's Flour Co., Minneapolis, Minn. ....Pillsbury's Fancy	16.	18.2
Russell Flour Co., Albany, N. Y...Regular	15.	18.2
Northwestern Consolidated Milling Co., Minneapolis, Minn....Planet	15.	18.
Washburn Mills, Minneapolis, Minn. ....W. C.'s Pure	16.	18.
D. H. Grandin Milling Co., Jamestown, N. Y. ....Red Leaf (4)	15.8	17.8
Thompson Milling Co., Lockport, N. Y. ....Angelus	15.	17.8
Waggoner-Gates Milling Co., Independence, Mo.	15.	17.8
H. Brown & Son, Boston, Mass...Onward	17.	17.6
Hecker-Jones-Jewell Milling Co., Buffalo, N. Y. ....(5)	14.6	17.6
Russell-Miller Milling Co., Minneapolis, Minn. ....Occident	15.	17.6
Griswold & MacKinnon, St. Johnsbury, Vt. ....Xtragood	16.	17.3
National Milling Co., Toledo, Ohio	15.	17.3
Quaker Oats Co., Chicago, Ill....Buckeye	15.5	17.3
J. H. Hewitt, So. Royalton, Vt...Our	..	17.3
Federal Milling Co., Lockport, N. Y. ....Lucky (3)	15.	17.3
Ogdensburg Milling Co., Ogdensburg, N. Y. ....Ogdensburg	..	17.1
Chas. M. Cox Co., Boston, Mass...Wirthmore	16.	17.1
Grafton Roller Mills Co., Grafton, No. Dak. ....Grafton	16.	17.1
F. W. Stock & Sons, Hinsdale, Mich. ....Superior	16.	17.1
E. W. Bailey & Co., Montpelier, Vt. ....Bailey's Fancy	16.	17.1
Quaker Oats Co., Chicago, Ill....Buckeye	15.5	17.1
National Milling Co., Toledo, Ohio	15.5	17.1
Barber Milling Co., Minneapolis, Minn. ....White Satin	16.	16.9
Detroit Milling Co., Detroit, Mich. ....Splendid Heavy	15.	16.9
Northwestern Consolidated Milling Co., Minneapolis, Minn....	15.	16.9
Sheffield-King Milling Co., Minneapolis, Minn. ....Gold Mine	15.9	16.7

"Coarse wheat bran and red dog flour with less than mill run of ground screenings."

"With ground screenings not exceeding mill run."

"Red dog low grade flour, wheat bran with mill run screenings and 0.50 percent salt."

"With mill run screenings."

WHEAT MIXED FEEDS (cont.)

Bill, Bell & Co., Ogdensburg, N. Y.	Wise King	16.	16.7
Briton Milling Co., Briton, So. Dak.	Favorite (3)	14.4	16.7
F. W. Stock & Sons, Hinsdale, Mich.	Monarch Fancy (5)	16.	16.7
Commercial Milling Co., Detroit, Mich.	(1)	15.	16.4
Duluth-Superior Milling Co., Duluth, Minn.	Boston	15.	16.4
Lexington Roller Mills Co., Lex- ington, Ky.	Thoroughbred	15.8	16.4
Wm. A. Coombs Milling Co., Coldwater, Mich.	(3)	15.	16.3
Sheffield-King Milling Co., Min- neapolis, Minn.	Gold Mine	15.9	16.3
C. W. Wager & Co., Philadelphia, Pa.	Middlesex (5)	15.	16.3
Red Wing Milling Co., Red Wing, Minn.	Go Far	16.5	16.
Valley City Milling Co., Grand Rapids, Mich.	Farmers' Favorite Cow	14.2	16.
National Milling Co., Toledo, Ohio	Pennant	16.	15.9
David Stott Flour Mills, Detroit, Mich.	Stott's	16.	15.8
Stratton & Co., Concord, N. H.	Stratton & Co.'s	15.9	15.
Williams Bros. Co., Kent, Ohio.	Kent	12.	14.9
Portland Milling Co., Portland, Me.	Champion	13.6	14.7
Alma Roller Mills, Alma, Mich.		15.1	14.7

FEEDING (RED DOG) FLOUR

Washburn-Crosby Co., Minne- apolis, Minn.	Adrian	17.	20.6
Northwestern Consolidated Mill- ing Co., Minneapolis, Minn.	XXX Comet	16.5	19.4
Pillsbury Co., Minneapolis, Minn.	XX Daisy	17.	18.9
Barber Milling Co., Minneapolis, Minn.	Fancy	18.	18.4
Washburn-Crosby Co., Minne- apolis, Minn.	Arlington	..	17.8
David Stott Flour Mills, Detroit, Mich.	Stag	15.	17.6
Russell-Miller Milling Co., Min- neapolis, Minn.		16.	17.3
Ogdensburg Roller Mills, Ogdens- burg, N. Y.		..	16.9
Geo. Tileston Mill Co., St. Cloud, Minn.	Gipy Choice	..	16.4
Hecker-Jones-Jewell Milling Co., Buffalo, N. Y.	Hecker's	16.4	16.3
Red Wing Milling Co., Red Wing, Minn.	Bixota	12.7	16.3

¹"With ground screenings not exceeding the natural run of wheat."

²"With ground screenings not exceeding mill run."

³"With mill run screenings."

DISCUSSION OF THE RESULTS OF INSPECTION

The character of the feeds sold during the past winter has been excellent. At no time in the 16 years during which the feeding stuff inspection system has been in operation, has so favorable an outcome been secured. Only 10 of 255 samples of goods needing guaranties and only 12 of 396 samples of goods actually guaranteed were deficient; and only 8 of the 12 deficient were one percent short, only 3 were two percent short and there was but a single serious deficiency. Guaranties rarely are omitted. Weed seeds, once a bane, are now less in evidence. The molasses feeds which formerly were atrocious in this respect usually appear quite free from unground weed seeds or screenings, a marked improvement. In short the situation appears to be thoroughly satisfactory so far as the guaranty maintenance is concerned. The following tabulation sets forth the situation:

PROTEIN GUARANTIES, ANALYSES AND DEFICIENCIES

	Number of samples	Protein guaranties range from	Protein contents range from	Up to or above protein guaranty	One percent or more below protein guaranty	Unguaranteed
Cottonseed meals	22	43 to 38	43.1 to 37.2	20	2	..
Linseed meals	14	36 to 30	38.6 to 32	14	..	..
Gluten meals	1	40	45.4	1	..	..
Gluten feeds	12	23.3 to 20	28.8 to 23.4	12	..	..
Distillers' dried grains ..	15	31 to 26	33.8 to 26.5	14	1	..
Brewers' dried grains ..	5	27.2 to 20.5	28.9 to 25.9	5	..	..
Proprietary feeds	85	26 to 4.6	30 to 4.6	78	7	..
High protein	29	26 to 20	30 to 19.8	23	5	1
Medium protein ...	16	18.5 to 15	20.2 to 11.8	14	2	..
Low protein	40	12.5 to 4.6	16 to 4.6	40	..	1
Hominy feeds	10	11 to 9	12.7 to 10.5	9	..	1
Provender	8		11.4 to 9.9	..	..	..
Corn meal	9		10.1 to 7.7	..	..	..
Dried beef pulp	4	8	9 to 8.8	4	..	..
Alfalfa	8	16.6 to 12	19.1 to 12.1	7	..	1
Calf meals	7	26 to 18	26.8 to 18.2	7	..	..
Oats, rye feed	4		18.4 to 12.3	..	..	..
Poultry feeds	72	48 to 10	52.2 to 9.6	70	..	2
Animal feeds	11	48 to 10	52.2 to 11.4	11	..	..
Poultry mashes	19	19 to 10	23.6 to 11.2	18	..	1
Scratch feeds	21	11 to 10	12.1 to 10.3	21	..	..
Chick feeds, etc. ...	21	12 to 10	16.5 to 9.6	20	..	1
Wheat offals*	147	18.5 to 12	19.9 to 14.7	139	2	6
Wheat bran	49	16 to 13	19.8 to 14.8	48	1	..
Wheat middlings ..	41	18.5 to 14	19.9 to 15.4	39	1	1
Wheat mixed feeds	46	16.5 to 12	18.9 to 14.7	44	0	2
Feeding (red dog) flour..	11	18 to 12.7	20.6 to 16.3	8	..	3

*Guaranties are not required on commercial provenders and wheat offals. Practically all wheat offals, however, are guaranteed, in order to meet the requirements of the laws of many states.

Cottonseed meal. Twenty-two samples representing 14 brands were analyzed. Two (Dirigo, sold by W. N. Smith of Baltimore, Md., 41 percent grade; Red Tag, sold by American Cotton Oil Co., Jackson, Tenn.) fell short by a little over one percent.

Linseed meal. Fourteen samples representing nine brands were found to be as good as the guaranty.

Gluten meals and feeds. One sample of meal and 12 samples of feed representing six brands were found to be as good as the guaranty.

Distillers' dried grains. Fifteen samples representing eight brands were analyzed. One (Dewey's, Dewey Bros. Co., Blanchester, Ohio) fell short by a little more than one percent. This showing is most gratifying as compared with the situation developed in previous inspections. Apparently makers of this class of goods are more careful than formerly.

Brewers' dried grains. Five samples representing three brands were found to be as good as the guaranty.

Proprietary feeds. High protein goods. Twenty-eight samples representing 19 brands were analyzed. Five fell by the wayside in respect to their maintenance of protein guaranties. In four cases the shortage was barely over the one percent tolerance (Quaker Oats Co.'s Blue Ribbon Dairy, Elmore Milling Co.'s Elmore Milk Grains, Burlington Flouring Co.'s Perfection Dairy No. 3, Clover Leaf Milling Co.'s Peerless Dairy). In one case (Quaker Oats Co.'s Blue Ribbon Dairy) the deficiency approximated two percent.

Proprietary feeds. Medium protein goods. Sixteen samples representing nine brands were analyzed. Two molasses feeds (Western Grain Products Co.'s Hammond Dairy, Northwestern Mills Co.'s Sugarota Dairy) were deficient, the former by two percent, the latter by nearly five percent. The latter shortage is excessive, the goods carrying but seven-tenths of the protein promised by their purveyors.

Proprietary feeds. Low protein goods. Forty samples representing 32 brands were analyzed. Every one met its makers' promises. It is easy to keep a promise which promises little.

An interesting comparison of protein promises and selling prices may be made, using these proprietary articles for the purpose.

	Number of brands	Protein guaranties	Average protein guaranty	Approximate average sell- ing price
High protein	22	20-26	24	\$35 00
Medium protein	12	12½-18½	15½	28 00
Low protein	29	4½-12½	9½	34 00

The following statement of guaranties and average selling prices of concentrates ought to be illuminating in this connection.

	Number of brands	Protein guaranties	Average protein guaranty	Average selling price
<i>High protein, 20-40%</i>				
Cottonseed meal	14	38-43	40—	\$34 00
Linseed meal	9	30-36	32+	40 00
Gluten meal	1	40	40	38 00
Gluten feed	6	20-23.3	22½	34 00
Distillers' grains	7	26-31	29½	36 00
Brewers' grains	3	20.5-27.2	24+	30 00
<i>Medium protein, 15-20%</i>				
Wheat bran	49	13-17	15	29 00
Wheat middlings	41	14-18.5	16	33 00
Wheat mixed feed	48	12-17	15½	32 00
Low grade (red dog) flour	11	13-18	17½	38 00
<i>Low protein, 8-15%</i>				
Hominy feed	10	9-11	10	31 00
Corn and oats	8		10½*	34 00
Corn meal	9		9	32 00
Alfalfa meal	6	12-16.5	12½	35 00
Dried beet pulp	3	8	8	30 00
<i>Poultry feeds</i>				
Meat scraps, meat and bone meals	9	10-48	40	58 00
Mashes	14	10-19	16	45 00
Chick feeds	17	10-12	11	47 00
Scratch feeds	19	10-11	11½	42 00

*Analysis.

So far as the high protein ready-rations are concerned it may be said that they seem to be thoroughly desirable combinations; that with rare exceptions high class ingredients are used in constructing them; and speaking broadly, that the same materials purchased in local markets at the local prices of the past winter can be combined by the farmer on his own farm for a dollar or so less per ton. This statement is based on calculations which involve the use of reasonable proportions of the ingredients claimed, sufficient in each case to meet the guaranty statement made by the manufacturers. This means, therefore, that as feed prices now are quoted, and taking into account the cost of mixing at home, the prices asked for these high protein rations are not exorbitant; neither, on the other hand, is there any monetary saving as a rule in their purchase as compared with buying their ingredients.

The molasses and stock feeds are of a different sort. Among the list of ingredients declared by the manufacturers of the high protein foods one finds but rarely the acknowledgment of the use of a manufacturing byproduct of relatively inferior feeding value. It is quite otherwise with the lower grades. Among the molasses and stock feed

statements one finds such ingredients as "ground grain screenings," "clipped oat byproducts," "ground and bolted grain screenings," "re-cleaned grain screenings," "oat clippings," "flax plant byproduct," "cooked sphagnum," "grain screenings," "oatmeal byproducts (oat middlings, oat hulls, oat shorts)," "ground re-cleaned grain screenings," "oat hulls," "cobmeal," "screenings," "ground corn and cob." Yet the prices asked for goods which proclaim the carriage of such material is only from \$2 to \$5 less per ton than those asked for higher graded goods. The fact that materials like "oat clippings," "cobmeal," "ground grain screenings," etc., are not offered as such on Vermont markets and that their commercial values are not known to the writer, prevents the calculations upon which was based the above statement as to the relative money values of ready mixed and home mixed high protein rations.

Hominy feeds. Ten samples representing eight brands were found to be as good as the guaranty.

Dried beet pulp. Four samples representing three brands were found to be as good as the guaranty.

Alfalfa meals. Eight samples representing seven brands were found to be as good as the guaranty. One was of very high grade and well worth considering at Vermont selling points, a thousand miles east of the point where the crop was grown. Others were in a different class and excellent things *not* to buy.

Calf meals. Seven samples representing four brands found to be as good as the guaranty.

Poultry feeds. Seventy-two samples, representing 53 brands were analyzed and all met their guaranties. Two, however, were unguarantied.

Wheat offals. Judging by the number of samples drawn in this and previous inspections it is safe to say that the wheat offals are in the highest favor among Vermont dairy feeders. One hundred forty-seven samples were analyzed. Six were not guaranteed, which is no sin in Vermont. Two, however, failed to meet the guaranties which their purveyors made for them.

CONCERNING THE CORN CROP

By J. L. HILLS

INTRODUCTION

For seven years the annual feeding stuffs inspection bulletin has been made the vehicle for the purveyal of an informational article dealing with feeding practice, following in this respect in the wake of the fertilizer control bulletins in which informational articles concerning fertilizers were issued for the first time in 1902. This practice is warranted by the somewhat wide latitude which is accorded the Station by the feeding stuffs law which permits it to include in its feeding stuffs inspection bulletins "such additional information in relation to the character, composition, value and use of such feeding stuffs as circumstances may advise." The feeding stuffs bulletins which have been of this character in the past have discussed the following matters:

- 1908. No. 138 The viability of weed seeds in feeding stuffs.
- 1909. No. 144 Concerning the manufacture and nature of feed; the economics of feed purchase; the formulation of grain rations; statement concerning feeding.
- 1910. No. 152 Principles and practice of stock feeding, including discussion of animal nutrition, feeding standards and sundry economic considerations, as well as a full glossary and tables displaying the several feeding standards, the average composition of roughages and concentrates, digestion coefficients and digestible ingredients and a "convenience table" giving the pounds of dry matter and digestible ingredients.
- 1911. No. 158 Concerning feeding standards, being a review of the energy value scheme, Minnesota station findings and Scandinavian feed unit system; summer soiling suggestions.
- 1912. No. 164 Condimental feeds.
- 1913. No. 171 Concerning the Vermont hay crop.
- 1914. No. 180 Concerning feeding practice; including discussions of what the cow does with the feed she eats, how to balance a ration, advisable roughages to grow, advisable grain feeds to buy, suggestions as to profitable milk production and balanced rations for hens.

It seemed advisable, since the hay crop had been discussed in 1913, to review this year the other principal Vermont roughage, the corn crop; and the present article is the result. There is nothing whatever original about it. It represents simply a compilation. Many federal and state publications as well as several of the more recent books dealing with corn were used in its construction. The writer does not pretend that the article is a complete monograph or anything more than a somewhat fragmentary presentation of the subject, loose jointed and none too well built.

ORIGIN OF THE PLANT

"Indian corn," or "maize," the *Zea Mays* of the botanist, is of the manner born in America. Its original home appears to have been the highlands of Mexico. Its distinctive name "maize" is derived from a Haytian word "mahiz," which itself is said to be an Arawak (Indian) word of South American lineage. Its more common name, "Indian corn," is a specific, its most common name "corn" a generic and unfortunate title, since throughout the eastern hemisphere, both in biblical and in modern times, the word "corn" has been used synonymously with the word "grain."

Thorwald, brother of Lief Erickson, the Viking, reports in 1002 A. D. "a wooden crib for corn" at a point possibly on the southern New England coast. Four hundred years ago Columbus, Cortez and De Soto found it growing in abundance in the Caribbean Islands, Mexico and Florida, respectively; and later explorers report its wide distribution. For example Jacques Cartier and Champlain report it in the St. Lawrence valley. During these times it does not appear to have been known in the eastern hemisphere.

Corn cuts but little figure in Europe, Asia or in Africa. It is not grown largely on those continents, neither is it imported to any appreciable extent. Attempts have been made to popularize corn among the European poor without permanent success. Only $2\frac{1}{4}$ percent of the crop grown in the United States is exported. Almost the entire crop is fed on the farms which produce it, for fattening beef and pork or for milk making. In some sections the ear only is used, in others—and increasingly and particularly as the practice of dairying spreads—the entire plant is utilized.

EXTENT OF THE CROP

Everyone knows what Indian corn is, knows that both grain and stalk are used, that it enters into the dietary of both human and brute creation, that many products are made from it, such as glucose or grape sugar, sundry starches, grits, dextrins, corn oil, rubber substitute, distilled spirits, alcohol, corn down, corn meals, corn germ meal, gluten meals and feeds, and corn distillers' grains from the kernel; pipes and fuel from the cob; cellulose for packing and the manufacture of explosives, paper pulp, pyroxylin, etc. from the stalk. Not everyone, however, appreciates its preeminence. King Cotton no longer reigns if, indeed, he ever ruled in America. In terms of acreage, of yields, and of money values, corn outranks all other crops, with hay, cotton and wheat following in the order given in money values. Acreages and values have doubled within 40 years. Every fourth acre—almost—of improved land in the United States is a cornfield. It is a vitally important crop in most, and an important crop in every American state. Most of our Indian corn grows in the seven cornbelt states and in Texas. Illinois, Iowa and Nebraska grow as many bushels of corn as do 40 of their sister states and, together with Missouri, Kansas, Indiana and Ohio, grow three-fifths of the entire crop, one-third is grown in 40 states and the rest springs from the vast bosom of Texan soil. Seventy-eight percent of the world's crop is grown in North America and 73 percent within the borders of this country. Ninety-seven and three-fourths percent of our production is used at home. The per capita production is between 25 and 30 bushels. Hartley calculates that the 1906 crop in the United States, loaded 50 bushels to a wagon, 20 feet to each wagon and team, would encircle the globe at the equator nine times.

While the cornbelt states lead in gross production, New England leads in acre yields. During the 10 years, 1897-1906, Connecticut, Massachusetts and Maine headed the procession of the 48 sisters with acre yields of 36, 35.6 and 35.1 bushels. Vermont stood seventh in line with 34.5 bushels to her credit. Last year Vermont's average acre yield was phenomenal, 47 bushels. Only one state equalled and none surpassed this yield. The average for the country as a whole was 25.8 bushels. The cornbelt states' average acre yields during the 10 years from 1897 to 1906 were: Ohio, 34.9; Indiana, 34.5; Illinois, 34; Iowa, 32.5; Missouri, 27; Nebraska, 27.7; Kansas, 22.1.

The preeminence of the United States in corn growing is not accidental. It is not due to soil conditions only or mainly, but also to

climatic conditions, to moisture and temperature relations. The latitude, elevation and temperature conditions throughout the cornbelt states are favorable. The rainfall and its distribution are main controlling factors. As has been brought out clearly by Smith,¹ the cornbelt summer rainfall curve year after year parallels the corn yield curve. In no other section of the world do such large areas of suitable soil coexist with a climate providing a long succession of hot days and nights and a well distributed rainfall. (In this connection see pages 339-340).

SUBSPECIES

Maize is a highly variable plant which has adapted itself to diverse environments from the latitudes of the lower fifties to the tropics. There are several fairly well recognized races or subspecies. Sturtevant² has classified several varieties of *Zea Mays*. The pod, soft and starchy sweet corns (vars. *tunicata*, *amylacea* and *amylea-saccharata*) are simply curiosities, of no practical bearing. Pop, sweet, flint and dent corns (vars. *everta*, *saccharata*, *indurata* and *indentata*) have economic values. These are all familiar to farmers, yet may be briefly described from the standpoint of the botanist as follows:

Pop corn. Kernels are small and contain relatively large proportions of horny material, the so-called "corneous endosperm," from which the moisture present cannot readily escape, a condition which induces "popping."

Sweet corn. Kernels, as compared with flint and dent corns, are notably translucent, and on maturing become wrinkled or shriveled and contain a large proportion of actual sugar.

Flint corn. Kernels contain in the center a soft, starchy material, the so-called "starchy endosperm," encased within an entire wrapping of horny material, the "corneous endosperm," the proportion varying with different varieties. It is smooth at maturity, often eight rowed and grows further north than dent corn, matures earlier and is the type usually grown throughout northern New England.

Dent corn. Kernels contain both endosperms as do the flint varieties, but the starchy endosperm, instead of being entirely encased in the corneous form, extends to the top of the kernel and, drying and shrinking, pulls in and "dents" the apex. It is the common field corn of the

¹ U. S. Dept. Agr., Yearbook, 1903, pp. 215-224.

² U. S. Dept. Agr., Of. Exp. Sta., Bul. 56, pp. 12-20 (1899).

cornbelt states and the export corn. Doubtless nine-tenths of the world's corn is of the dent type.

While it will be impossible in this bulletin to go into details as to the multifarious operations in connection with the planting, cultivation, harvesting and feeding of the corn crop—details which would fill a book and have filled many—a few pages may be given over to the consideration of the subject under the general heads: (1) Seed. (2) Soil. (3) Harvest. (4) Feeding.

1. SEED

It has been said—and by those whose special opportunities and information entitle them to express an opinion to which weight properly may be accorded—that the corn production of the United States could be doubled without materially increased outlay of work or money. The desirability of such a procedure as a nation-wide effort perhaps may be open to question. Too much corn might be grown. But for an individual to grow more on less land, to raise 52 bushels on an acre instead of the average 26 bushels, would be worth while; for the labor and cost of soil fitting and cultivating and of harvesting would not be increased materially.

Untoward weather conditions often are to blame for low yields; indeed, it rarely happens that the weather is ideal throughout the growing season. Since the weather, like the poor, always is with us, it behooves the farmer to make the best of it, not pessimistically but optimistically, that is to say, he should make the best of it by making his crop do its best with the weather it has to work with, by taking advantage of the existing conditions. In this connection, see pages 339-345

However, there are other and more controllable conditions which make for low yields, the more obvious being poor seed and poor soil preparation.

SEED IMPROVEMENT

Many of our American farmers take little thought for the morrow as to their seed, while paying considerable sums for fertilizer and for fitting their soil. They are careless in selecting home-grown seed or heedless in purchasing seed. Productivity, uniformity and adaptability to one's soil and climate are vital considerations in choosing a variety. Indeed, varietal names are relatively unimportant, if not in

many cases meaningless. The practices of the seed trade have not made for standardization. The readiness whereby mixing may be wrought through corn pollination induced by the wind, complicates the problem. Hence varietal names may mean little. One lot of Sanford seed corn, a variety commonly grown in Vermont, may be quite unlike another, and yet seed producer and seed dealer be innocent of the sin of substitution. Identical seed, planted and grown for successive years in different latitudes or longitudes, may become so modified by environment in a series of years that the remote maize cousins are totally unlike.

VARIETIES

Variety trials were much in evidence a generation ago, even as late as ten years ago, but at the present time less weight is accorded to the results of such trials; for it has been abundantly proven that even when using identical varieties and identical seed, widely divergent yields may be secured at different points or in different seasons or, indeed, on different plots on the same apparently uniform field. For example, the Illinois Station¹ secured from 13 plots on one trial area, using one variety and one source of seed, yields which ranged from 46 to 101 bushels per acre.

Doubtless there are a thousand named varieties but it is doubtful if there are a thousand different kinds of corn. Many varieties bear different names in different sections; many have a common origin. Then, too, a standard variety readily becomes modified through environmental influences.

"What variety of corn shall I grow?" is asked frequently. This question is answered more easily in Iowa or Ohio than in Vermont. Vermont is a north and south state and an up and down state. Alburg lies 150 miles north of Pownal; Lake Champlain's "beauteous breast" lies only 99 feet above sea level, whereas Mansfield's "rugged crest" rears its head almost 5,000 feet above sea level. Furthermore, her surface is so mountainous that the grade and direction of the slope cuts a considerable figure in the determination of this matter. Her climate is sufficiently uncertain so that varieties which mature in a given locality some years utterly fail to mature in other years. And, finally, she lies near the northern limit of successful corn culture. On these accounts there is no "best" variety for Vermont. The writer has been accustomed for years in endeavoring to answer this important question to

¹ Ill. Sta., Bul. 46, p. 353 (1897).

hedge, to dodge, to follow the example of the Delphic oracle, to say in short that that variety is best in any locality which will produce in a normal or average growing season the largest amount of digestible dry matter to the acre, provided that in producing it the ear is likely to glaze before or by the time when autumnal frosts are apt to occur.

Montgomery¹ suggests for New England and New York "8-row and 12-row Yellow Flint, King Philip and Canada Smut Nose" varieties (flint) and "Pride of the North, White Cap, Hall's Gold Nugget and various acclimated local varieties" (dent). He says, furthermore, that Leaming, Hickory King, Eureka Ensilage, Burrell and Whitman and Evergreen Sweet are grown for silage. It goes without saying that conditions on Long Island and Cape Cod are quite unlike those obtaining in northern Vermont where, as a rule, flint varieties only should be used.

Speaking broadly, seed grown in essentially the same latitude is to be preferred over that grown south or north of the place where it is to be used. The location of the seed upon the ear, whether from the butt, the tip, or the middle of the ear, so be it is mature, seems unimportant.

CORN BREEDING

Corn breeding has been practiced in a more or less haphazard way for a considerable time, and scientifically for nearly a generation. In the last analysis corn breeding is merely a rigid process of seed selection, pursued for a long series of years with some definite point in view, the modification of some particular physical or chemical characteristic. The main points held in view in this class of work usually have been the production of an ear which would shell the largest possible percentage of grain to cob, an ear showing uniformity, symmetry, and well filled tips, with grains wedge-shaped and long, deep set and compact. Sometimes breeding has been done for special purposes, such as the furnishment to starch and glucose factories of kernels relatively low in their protein content and relatively high in their starch and oil contents, or the furnishment for the purposes of the feeder of a kernel relatively high in protein content. More breeding work has been done with dent than with flint corn.

GATHERING AND STORING SEED CORN

The demand for good, well-bred seed corn, true to name, is insistent. There are many men at work breeding corn, and improved

¹Montgomery, E. G., *The Corn Crops*, p. 188 (1913).

strains are being developed. Varietal names are legion and sales not always true to name. If purchases must be made in open market, they should be made as ear corn, in order that one may know the more certainly what he is getting. The crop depends on the seed.

Farmers growing their own seed should be sure that it is thoroughly dry before it has to withstand severe weather; that it is chosen and husked early in the fall, lest heavy frosts impair its vitality; that selections are made from the best developed section of the crop; that more ears than are needed should be saved so as to allow for discards; that the seed is not piled lest it mold but is spread out in a dry, well ventilated room, or, later, as is the Vermont custom, hung under the roof of the porch or in some other protected place in "traces"; that in the winter careful choice is made of the ears and a sufficient number of well shaped and well filled specimens chosen, ears showing well formed kernels, ears shelling out a large proportion of kernels; and that viability is determined. "An ounce of prevention is worth a pound of cure." Autumnal carelessness begets spring worry. "The mill will never grind with the water that is past"; neither will it grind corn that never grew because the seed was not properly saved during the preceding fall.

It is worth while in a good seed corn year to save enough seed for two or three years. Gathered early and carefully, its viability should be better than that of seed which is gathered carelessly or selected from the crib in the spring. In the spring of 1912—a poor seed year—the federal seed laboratory compared over 1,700 samples of farmers' seed with 73 samples of selected seed, gathered early and dried early. The averages were 81 and 98 percents respectively.

Hartley¹ says touching the preservation of seed corn during the winter that "seed corn may be greatly reduced in vitality by injudicious care during the winter"; that "some do not give the seed as good treatment as they might easily do"; that "any means that secures a thorough drying of the seed ears soon after they ripen, before freezing weather, and keeps them dry until the seed is planted will be a success. * * * A thorough drying of the seed ears, by artificial heat if necessary, and their preservation in a dry atmosphere and at a steady temperature is strongly recommended." He further says, touching the advisability of buying seed corn, that growing for years on the same farm does not cause seed to "run out," but, rather, the lack of attention to proper seed selection.

¹ U. S. Dept. Agr., Yearbook, 1902, pp. 550-552.

He says further that "it is deemed highly advisable to improve corn in the district and on the kind of soil where it is to be afterwards grown. It is true that a well-bred variety may sometimes be sent hundreds of miles from the place where it was improved and there be found superior to the native varieties with which it comes in comparison, while, on the other hand, a change in the conditions of soil and climate may cause a change in the corn or its habits of growth, so that a valuable variety for one state may be worthless for another state. For this reason extensive importation of seed corn from another locality where the soil and climatic conditions may be different should not be made without first testing the variety on a small scale.

"To produce a desirable grade of seed corn requires considerable attention and work, but the better quality and larger quantity of corn that will grow from it will more than pay for the labor. Any corn grower who has not the time, ability, or a suitable location to grow and select seed corn of a high grade, should buy his seed and willingly pay several dollars a bushel for it, but he should be sure that the seed he buys has been bred and selected. One safeguard in buying is to insist that the seed be delivered as ear corn. Sellers of seed corn offer several reasons for their unwillingness to ship seed corn on the ear, but if honestly expressed, the chief reason would be that by so doing they are unable to dispose of poor and small ears. When viewed in the proper light there are no good reasons that will prevent the selling and shipping of seed corn on the ear, and certainly as much profit can be made by selling good seed corn at an advanced price as by selling for seed purposes and at low prices corn which it is unwise for anyone to plant. The reform can best be accomplished by all who buy seed corn insisting that it be delivered on the ear. Growers then at least know from what kind of ears their seed was shelled. Seedsmen find it to their profit to meet the demands of their patrons, and if the demand for unshelled seed corn becomes great they will of necessity meet the demand. As soon as it becomes the universal practice to accept no seed that has been shelled, a great step will have been taken toward the raising of the average production per acre, for it will take from unscrupulous men one means of imposing upon the growers by the sale of poor seed.

"Properly grown and selected seed will often produce 15 bushels more corn per acre than unselected seed of the same variety. A bushel of seed will plant six or more acres, so that, estimating corn at 30 cents per bushel, such seed corn bears a money value of \$27 per bushel."

Hartley further says¹ that the average acre production is 26 bushels (in Vermont it is one-third greater) ; that in practically every section of the country some farmers grow four times as much as this ; that seed selection is the least expensive way of increasing yield ; and that the usual scarcity of good seed corn is due to delay and negligence which can be prevented by autumnal selections at ripening time. He states that "until a community has its experienced and honest corn breeder, the best place for the farmer to obtain seed corn is from fields on his farm or in his neighborhood that were planted with a variety that has generally proved most successful in that locality."

He decries the common feeling that seed is good simply because it will grow and defines first class seed as that which is

"(1) Well adapted to the seasonal and soil conditions where it is to be planted.

(2) Grown on productive plants of a productive variety.

(3) Well matured, and preserved from ripening time till planting time in a manner that will retain its full vigor."

He holds that one should "at corn-ripening time drop all other business and select an abundance of seed corn. The process is too important to be conducted incidentally while husking. When selecting seed corn give the process your entire attention. Get the very best that is to be had and preserve it well, and your increased yields will return you more profit than any other work you can do on your farm.

"The only proper way to select seed corn is from the stalks standing where they grew, as soon as ripe and before the first hard freeze.

"As soon as the crop ripens, go through the field with seed-picking bags and husk the ears from the stalks that have produced the most corn without having any special advantages, such as space, moisture, or fertility. Avoid the large ears on stalks standing singly with an unusual amount of space around them. Preference should be given the plants that have produced most heavily in competition with a full stand of less productive plants.

"In all localities the inherent tendency of the plant to produce heavily of sound, dry, shelled corn is of most importance.

"Late-maturing plants with ears which are heavy because of an excessive amount of sap should be ignored. Sappiness greatly increases the weight and is likely to destroy the quality."

¹U. S. Dept. Agr., Farmers' Bul. 415 (1910).

2. SOIL

THE CLIMATE AND CORN

The sum totals and the fluctuations of the climatic factors bear a close relation to the growth of the corn crop. An inadequate, a too adequate, or an ill distributed rainfall, an untimely frost, a mighty storm, or a hot wind spell disaster. One cannot regulate the climate, but can at least try so to plan his crop as to cooperate with rather than to antagonize nature.

Corn is a sun-loving plant of tropical origin; but it is notwithstanding a flexible crop. It has accommodated itself to its environment, it has become modified through the centuries. Some varieties mature in 80 days, others need 200 days, being thus adapted to growing seasons of divers lengths. The length of the growing season is the first limiting factor in corn growth. In Vermont the late spring and early fall frosts usually are about 150 days apart, whereas in southern New England they are from 170 to 200 days apart. The growing season of a corn crop should be from 20 to 30 days less than the average length of the theoretical growing season, in order that there may be greater likelihood of avoiding disaster at seed time or at harvest. In other words, farmers are apt wisely to choose varieties which are likely to mature in the shortest probable season.

Sunlight plays a leading rôle in the drama. All plant life as well as all animal life is dependent on sunlight, although it can exist if certain artificial lights are substituted. Sunlight enough to mature corn shines at 70° north latitude, unless the weather is inordinately cloudy; but of course other limiting factors prevent corn from reaching maturity in these high latitudes.

The rainfall really is the essential variant, the prime limiting factor. Under ordinary field conditions an acre-foot of water is needed to grow a good corn crop, somewhat more than half of which is used by the crop and somewhat less than half of which is lost in the runoff, by evaporation, by seepage etc. An average loam soil in good tilth should contain about half this supply stored from winter accumulation within the root area; and the rainfall should supply the residue. It should supply more than this residue, lest there be a lack at some crucial period. Indeed such lack is apt to occur more or less frequently in many growing seasons; and it is to meet just such lacks, to prevent just such lapses, to bridge over just such hiatuses, that the practice of irrigation in humid climates is the rule in the thickly popu-

lated countries of the Orient and is becoming established east of the Mississippi; as is set forth in full in bulletin 182, which is free for the asking. Furthermore, it is the better to cope with this situation, brought about by lack of a seasonal rainfall or its unhappy distribution, that the farmer assiduously tills his crop in June and July, using the cultivator in lieu of the irrigation ditch, as it set forth on page 343.

SOIL IMPROVEMENT

The series of fertilizer bulletins which was inaugurated with bulletin 93 in 1902, year by year has discussed matters more or less closely related to soil improvement, as may be noted by the list shown on page 388 of bulletin No. 190. Nos. 108 on farm manures, 123 on soil moisture and cultivation, 130 on soil bacteria, 135 on soil deterioration, green manuring and humus, 160 on limes and liming, 173 on drainage, 182 on irrigation and 190 in crop rotation—several of them now out of print—were pertinent in this connection. This is not the place to repeat what was said therein. Anyone interested can receive copies, if in print, for the asking. However, without going into details it may be said that some soils inherently are ill adapted to growing corn. They lack humus, are ill drained, or are too clayey. The use of manure, the plowing under of green cover crops, especially legumes, the use of drain tile or of lime should help such lands. In many sections the green manuring system has worked wonders, proving the cheapest means of fitting permanently large areas for adequate crop growth.

An ideal corn soil should be deep, moist, warm and well drained; deep, in order that roots may gather ample supplies of plant food and moisture; moist, since the corn plant's usage of water is tremendous, for from 14 to 20 tons must needs be transpired from the surface of the leaves in the production of a bushel of corn; warm, because the plant is of tropical ancestry, needing a higher soil and atmospheric temperature to ripen the crop than do the grain or grass crops; well drained, since a sufficiently free soil air circulation must be provided and removal of excess moisture secured so that roots may ramble. It should be a fine, mellow loam.

The moisture relations of the soil are important, as has been set forth at some length on page 339. Indeed, taking one year with another, it is safe to say that water shortage or surplusage more often has been the controlling factor in crop growth than any other one thing. It

was on this account that the recent bulletins on drainage and irrigation (173, 182) were issued. These bulletins discussed the removal of surplus water and one means of supplying a deficiency. In bulletin 123 (1904), long out of print, the relationship of cultivation to moisture deficiencies was developed and remedial suggestions advanced. This bulletin set forth the well known proposition that through adequate cultivation soil water can be retained in quantities large enough materially to aid crop growth. Crops need large water supplies and, lacking them, are stunted in their growth. A corn crop needs 10 to 15 inches of water during the season, half of which is absorbed by the roots and passes off through the leaves into the air. Seasonal rains and snows may amply supply the soil and subsoil, but wind and sunshine may seriously deplete the supply unless the evaporation from the soil surface is lessened through proper cultural methods. So far as soil moisture is concerned wind and sun are in a sense a detriment. What profiteth it to a crop that moisture passes into the air directly from the soil and concentrates soluble plant food on the soil surface? Only that which flows through the plant and into the air aids its growth and conveys plant food into its tissues. Obviously cultural methods should be such as will tend to direct soil moisture into plant channels; and this is accomplished by soil mulches. The thorough loosening of the soil surface for a depth of two to three inches so disarranges the capillary tubes of the soil through which water rises from the lower soil level to the plant root areas that evaporation is retarded and root imbibition enhanced. A fine, dry mulch frequently renewed, particularly after rains, constitutes a blanket of loose, finely powdered soil. Thus the harrow and the weeder, the cultivator and the hoe feed crops, furnish food and drink, and act in lieu of the fertilizer and of the irrigation ditch.

PLANTING AND CULTIVATION

Many experimental trials have been made at several American experiment stations with a view of determining the proper thickness and depth of planting, the most advisable distance between the rows, between the hills and between the stalks in the row. The results have been quite dissimilar and generalizations are hardly warranted. However, the following statement may be ventured, but should not be taken too literally.

Depth. Shallow planting seems best save in very dry weather, when it may be deepened a little to advantage. When the soil is in good tilth and climatic conditions favor, from one to three inches may serve, varying somewhat according to soil types.

Distance. Thick planting tends to increase the proportion of leaves and grain and to decrease the proportion of stalk, thus increasing the value of the fodder, the grain, however, occurring usually in the form of small and ill matured ears, largely nubbins.

The opposite results usually are attained from thin plantings. Individual plants naturally grow best and mature most successfully when they are accorded their "place in the sun." A Maine station trial¹, conducted for three years, furnished results probably fairly applicable to Vermont conditions. When kernels were planted nine inches apart a larger green crop and a greater dry weight were secured than when they were planted six to twelve inches apart. Inferior ears were grown on the 6-inch planting.

Hill or drill. Results of comparative trials have proven indeterminate. Either three or four stalks to a hill usually gave the best results, or the equivalent amount of seed, if drilled. From four to seven quarts of seed are needed per acre.

Should the corn field be harrowed after the crop has been planted? Yes or no, according to circumstances. Yes, if cold, rainy weather has delayed germination and the soil has become hard and weed infested; no, if the soil has been well fitted in advance and the planting has not been done too early; yes, perhaps, on the heavier types of soils and where witch grass abounds; no, on true corn soils which are not too weedy.

In this connection it may not be amiss to repeat certain pertinent statements contained in bulletin 149 entitled "A Practicable Method of Killing Witch Grass."

"* * * The process contemplates the alternate moving of the soil first towards and then away from the row, over and over again. After the first ridging and cultivation, only about two inches of surface soil are moved or in any way disturbed. The general aim is to keep this 2-inch mulch so fine and light that nothing can take root in it, and that little soil water can evaporate therefrom. Whatever witch grass or other weed may come up through this mulch is torn out before it gets tough or makes growth enough to do harm. The great advantage which ridging affords is that the cultivator has something to work to-

¹Me. Sta. Rpt. 12, p. 30 (1896).

wards. If done properly, not to exceed three inches need be left in the row which the cultivator will not reach, whereas in ordinary cultivation twice as much or more is left untouched by the horse hoe.

(1) The first step in this special process consists of the ridging of the soil over the rows, using a disc hoe or any suitable tool, this being done before the corn is up, or at the latest just as it is showing its first sprouts above ground.

(2) Three days later, a 5-toothed cultivator, with side hoes such as are used in hilling potatoes turned backward, or 2-horse hoe, is run between the ridges, drawing the soil away from their sides, so that the subsequent harrowing can level them more effectually.

(3) On the same day, the small residues of the original ridges, left by the cultivation just described, are leveled with a smoothing harrow or a weeder, preferably the former. This treatment leaves a somewhat level surface.

(4) A week or ten days later, the cultivator again is run over the piece, thoroughly stirring the soil. A 2-horse riding cultivator will do a more thorough job than will the single-horse mechanism, which commonly needs to be run twice the same day, or in closely succeeding days.

(5) The same day it is gone over again as in paragraph 3 with smoothing harrow or weeder, which serves still more to level ridges and to secure an adequate mulch.

(6) Thereafter cultivation as in paragraph 4 is done, thoroughly and in a shallow manner each week or ten days, so long as it can be done without injury to the crop, the oftener the better.

(7) And, finally, one good hand hoeing is called for in mid-July.

The successful conduct of this special process of soil culture and weed killing contemplates the movement in alternation of the surface soil to and from the row, and frequent interference with the rooting habits of the witch grass. The surface soil is first piled on top of the row then, before it smothers the corn, the larger part thereof is spread out between the rows, first by the cultivator with side hoes drawing the soil away from the ridged rows and then by leveling with the smoothing harrow. This soil then is thrown back and up towards the rows again, and yet again; and, then, almost at once pulled back again with the weeder run across the rows. Further cultivations serve to pile up the soil somewhat in a slight ridge between the rows, and the weeder following not only levels the ridge, but works down the surface of the row slightly. However, the surface of the

row is left slightly higher than the area between the rows. This causes the weeder to 'take hold' in the row where it is most needed, and permits the cultivator to be run much closer to the corn plants without injury than otherwise could be done."

CORN ROOTS

The location of the corn roots in the soil at different stages of the growth of the crop has vital relationship to the manner of cultivation; for any system of cultivation which tends to destroy crop roots hinders crop growth.

Corn roots, if they can, occupy a soil completely; and the qualification "if they can" is affected by the adequacy of soil preparation. If the soil is ill drained the crop throws out shallow roots, for roots can not penetrate the soil areas which are water logged. If the soil is thin, if the ledge or hardpan lies near the surface, the roots must spread horizontally. If any other reason—and there are several—serves to limit the depth to which the roots may penetrate, so much the worse for the crop.

The root system of the corn plant spreads both horizontally and perpendicularly. The roots of plants in adjoining rows meet and pass early in life, and, as the weeks progress, descend three, four, five or more feet into the soil. Corn has no tap-root. It sends its initial roots downward, then throws out its roots sideways, roots which tend to rise closer to the surface as the crop advances in maturity. These lateral as well as the deeper roots throw out slender rootlets, the feeding organs, which ramify it throughout a wide radius of soil. It has been determined that the roots and rootlets of a single corn plant may exceed a mile in length.

Now these rooting habits control, or should control, the practice of cultivation. No damage can be wrought by deep cultivation while the plants are small and the roots relatively deep. But when these lateral roots and their feeding rootlets begin to reach up towards the surface, more care must be exercised and more shallow cultivation practiced. Such a procedure saves less water for crop growth than does deeper tillage; but of what benefit is it to save water through intertillage on the one hand and to destroy the plant's mechanism for using it on the other hand? Cultivation should be progressively shallowed as the crop grows larger. Obviously in a wet season the damage done by root pruning is not as serious as in a normal or in a dry sea-

son. The ideal time at which to kill weeds in a corn field is just before or as the first blades break through. The best time to fit the soil is before and not after planting.

When should corn be cultivated? How many times? No definite rule can be laid down other than to say that it should be cultivated when it needs it; after every heavy rain when a crust forms; when the dry earth mulch is destroyed or has become weakened. A slight rain in June or early July is often worse than no rain at all, since it tends to lessen the amount of water available to crop growth; for it crusts the soil, shuts out the air, reestablishes the capillarity connection with the subsoil which the cultivator teeth have broken, and thus promotes the evaporation of water from the soil surface. A close capillary connection between the subsoil water and the subsurface, two or three inches below the actual surface, is necessary in order that plants may feed, but at this point it should be broken; and this breaking of the water tubes is the primary object of intertillage.

Weeders are such slight implements that they can do little harm, and sometimes little good, save on soils already in excellent tilth. Cultivators, on the other hand, are more effective, as looseners of heavy and hard soils, as discouragers of the larger weeds. They are strong implements, capable of stirring the soil to a considerable depth. If possible they should be so arranged as to cultivate at various depths. Horse weeders and harrows serve a good purpose here, narrow shovels being more effective than broad blades. The kinds of cultivators are legion. Double or 2-row cultivators are favored in larger fields on level lands fairly free from stone. The shovel types are determined by soil, size of the corn, size and nature of weed growth. On sandy loam wide "sweeps" are favored, scraping along the soil at a depth of two to three inches, cutting off the weeds and dropping the soil flat behind them. The horse hoe is largely used in New England, adapted from tobacco culture mechanisms, with long, horizontal blades. Whatever form is used should be so adjusted as to leave the soil loosened as a fine and even layer. On the whole for general farm work, a form of cultivator carrying three or four medium sized, diagonally set shovels on either side seems preferable. The 2-row types work well on the larger fields, if these are well fitted and carefully planted. A one-horse, fine tooth mechanism is also needed for summer intertillage operations, one which will restore soil mulches without injuring the roots.

CORN IN THE ROTATION

Corn naturally fits into a rotation. It is what is known as a cleansing crop which benefits the entire rotation, whereas in its turn it is benefited by the growth of the legume which usually is included in the scheme.¹

FERTILIZATION

Corn is a gross feeder. It devours organic matter avidly. Next to the maintenance of an adequate water supply the furnishment of ample amounts of readily decomposable organic matter is a vital necessity, as a direct source of food supply, as a means of rendering soil constituents available to plant uses, as a means of bettering the physical condition of the soil and in order to promote its bacterial activities.² This organic matter is best supplied through the application of barnyard manures, green manuring and the introduction of legumes into the rotation.³

Multitudinous experiments have been made dealing with the fertilization of the corn plant, with results widely varying in their character. While definite rules cannot be laid down, a few generalizations seem warranted. Barnyard manure usually has been found to increase yields and to exert a residual effect in succeeding years. It is sometimes applied to the grass which precedes the corn in rotation; more often put on the corn ground and plowed under, or, perhaps better, thoroughly disced in before plowing; and sometimes applied as a top dressing on the fall plowing and disced in in the spring. This procedure has not always proved profitable. In the East manure, commercial fertilizer, or both together, commonly have been used. Speaking broadly, a commercial fertilizer carrying available phosphoric acid in considerable amounts, together with small amounts of nitrogen and potash, particularly if used with manure, seems as a rule to have proven most satisfactory. Doubtless the commercial fertilizers used on corn in this northern state should carry a considerable portion of their nitrogen in mineral forms, and, the writer is inclined to believe, preferably as nitrate.

Does it pay to fertilize corn? Montgomery⁴ reviews the experimental evidence relating to this matter and states that it seldom pays

¹For special article concerning rotation, see bulletin 190.

²In this connection see bulletin 135 on "soil deterioration and soil humus."

³In this connection see bulletin 190 on "crop rotation."

⁴Loc. cit. p. 145.

to use mineral fertilizers alone on land which does not ordinarily produce 20 bushels; that even on good land they rarely pay when applied directly to corn; that, furthermore, they rarely pay when applied to corn grown continuously in the same field or rotated with grain only; that as a rule they pay only when used in connection with a rotation where in manure or a legume crop or both are plowed under, in which case the minerals are best applied to the sod land, though sodium nitrate properly may be applied at times directly to the growing crop. This statement does not controvert the well known fact that quite commonly the use of commercial fertilizers brings about an increased production, but simply stresses the fact that this increase does not always, and perhaps does not usually, pay the fertilizer bill, unless manure, legumes, or both, are used in connection with the fertilizer.

The Bureau of Soils of the Federal Department has discussed this matter.¹ It states that in 31 years the American stations have reported the results of 6,394 tests of fertilizers with corn; that increased yields were more likely and greater when mixed fertilizers were used in lieu of single ingredients; that increases seemed to have been as pronounced on the more productive soils as on the less productive soils; that in the great majority of cases and on the average the increased yields did not pay the cost of the fertilizer, the statement being made that the average cost of the fertilizers used in all experiments was \$7.06 per acre, the average increase in crop was 9.2 bushels of shelled corn, worth at 60 cents per bushel \$5.52, indicating a net average loss of \$1.72 per acre; and closes with the statement that "much yet remains to be determined as to how fertilizers act before a rational and economical fertilization practice can be worked out."

REASONS FOR POOR CORN

Jerry Moore, a boy in his teens, grew in 1910 on an acre of rather light, coastal plain soil in eastern South Carolina, 228.7 bushels of corn, field weight. The average yield in the United States is but about one-tenth as much as this and in South Carolina about one-twentieth as much as this. How did it happen that Jerry grew so much and that his neighbors grew so little? Why is the average so low, when corn growers everywhere easily double and treble the average yield?

Jerry Moore grew his large crop because he cared for his prize acre tremendously well and fed it to the limit. The generality of corn

¹ Whitney, M. Fertilizers for corn soils. U. S. Dept. Agr. Bu. Soils, Bul. 64 (1910).

growers secure relatively low returns, not because of unfavorable climatic conditions—for we are told that the rain falls alike on the just and the unjust, and in most neighborhoods there are some growers who secure fairly good returns—but because soils are ill-tilled, ill-drained, or ill-nourished; and the remedies are adequate fitting of this soil, proper intertillage, underdrainage and the judicious use of manures and fertilizers.¹

INSECT, BIRD AND FUNGUS PESTS

Cutworms often are a serious menace. They are of many sorts. Their destructive work is more apt to be seen on spring plowed sod lands than on rotated fields, or on lands plowed early in the fall. They cut the plant off at the soil surface during the night, sometimes destroying entire fields. Fields severely affected may be thoroughly cultivated and, after a short interval, replanted. Deferred planting sometimes works well as a May and June starvation measure, since they are most active at this time. Crop rotation, with fields left in grass for not more than two years, usually proves effective. Poisoned bait is apt to be found an effective means when combating them in a small way as in the garden, using either bran, Paris green, molasses and water (bran 30 pounds, Paris green 1 pound, molasses 2 quarts, water enough to moisten) or cut green clover sprayed with an arsenical.

Wireworms (the larvæ of the "click beetle") sometimes are a pest in corn grown on sod land. They live for two years. Fall plowing, which breaks up the egg clusters, is a deterrent and the interjection of a grain crop at this point in the rotation helps. The grain crop is damaged, but usually can stand injury better than can the corn.

White grubs (the larvæ of the May beetle or June bug), often seen when plowing, are quite harmful. They live in the larval stage for two years and attack the corn roots. What is sauce for the wire worm is sauce for the white grub.

Chinch bugs and grasshoppers occasionally trouble in Vermont fields, but less often than in those further south and west. The grasshoppers caused much trouble this spring (1915). Plowed and furrowed strips serve to trap the chinch bug and "hopper-doers" and "catchers" may be used in fighting the grasshopper. The following extension service "brieflet," issued this spring and sent to every address in the Vermont experiment station mailing list, outlines an effective means of combating grasshoppers.

¹In this connection, see bulletin 135 on "soil deterioration and soil humus" and bulletin 173 on "underdrainage."

COOPERATIVE EXTENSION WORK
IN
AGRICULTURE AND HOME ECONOMICS
STATE OF VERMONT

College of Agriculture,
University of Vermont and
U. S. Department of Agriculture,
cooperating.

Extension Service
Brieflet No. 54
May, 1915.

POISON BAIT FOR GRASSHOPPERS

Formula. Wheat bran, 25 pounds; Paris green, 1 pound; cheap molasses or sirup, 2 quarts; oranges or lemons, 3 fruits.

Caution. Anything of this nature must, of course, be made and distributed with care, as poison baits may poison children as well as grasshoppers if placed where they are readily accessible.

Method of mixing. Thoroughly mix together the bran and Paris green. An ordinary washtub will answer for this purpose. Into a separate receptacle containing the molasses or sirup squeeze the juices of the fruit, then chop up finely the skin and pulp of the fruit and add this also to the molasses mixture, which is then diluted with two gallons of water. Mix the two together and add enough more water to bring the whole to a stiff dough. This amount of poison bait is sufficient to treat from 5 to 10 acres when properly applied. It should be borne in mind, however, that the fruit is the essential element of this bait, and if not employed 75 percent of the efficiency of the bait is lost.

Method of application. This poison bait should be applied to the area to be treated very early in the morning, before sunrise. To obtain the best results, the bait must be sown broadcast around the border and in strips 1 rod apart over the area to be treated. More than one application may be necessary. Broadcasting obviates the possibility of horses, cattle, sheep, poultry or birds being able to obtain a sufficient amount of poison in the field to kill or injure them. But under no circumstances should the bait be scattered over treated areas in piles or bunches for fear that birds or live stock might, under such circumstances, eat enough of the poison to prove fatal.

Issued by the University of Vermont, College of Agriculture, Extension Service, Thos. Bradlee, Director, and distributed in furtherance of the purpose of the cooperative agricultural extension work provided for in the Act of Congress of May 8, 1914.

Crows are friends or foes according to circumstances. However, they are surely a detriment to the newly seeded corn piece. Scarecrows, planting enough for both crow and crop, and the use of tarred or poisoned seed are recommended. The tarring may be done by rolling the seed corn in a slightly warmed or moistened kettle, using a small amount of diluted gas or coal tar, at the rate of a tablespoonful to six to eight quarts of seed, coating the tarred seed with ashes, road dust, plaster or the like in order to promote ease of planting. It is said that if a few crows are killed by corn soaked in strychnine, the field no longer will be molested.

Corn smut is the most common fungus disease. Every corn grower knows what it is. It injures and usually destroys individual ears, but rarely attacks other parts of the plant. Sometimes it does considerable damage, perhaps as high as one percent. The spores live

over winter in the soil or manure pile. It is harmless to cattle. The smutted ears should be burned and the spores kept from getting into the manure. No other effective remedy is known. Crop rotation and the use of manure a year ahead of the corn crop also help in its control.

3. HARVEST

The corn crop is harvested diversely in different locations and countries. In some sections—indeed throughout the non-dairy sections of the corn belt—the ears are plucked by hand and the stalks left in the field to be pastured by stock whenever fall or winter weather conditions favor or plowed under; in others the crop is “topped,” that is to say the stalk as far as and including the ear is harvested and the residue wasted; in others, and increasingly, the entire crop above ground is utilized. Sometimes the crop is gathered by man, sometimes by beast, as for example when swine are turned in to “hog off” or “hog down” the crop—a system rapidly growing in favor and proving very economical as a pork producer—and sometimes on mammoth fields it is harvested by machine pickers. These relatively wasteful processes seem strange to Vermonters, accustomed from time immemorial to utilize the entire crop; and yet 25 years ago many Vermont farmers were frankly skeptical as to the value of the lower portion or butts of corn stalks. This doubting attitude expressed “at an agricultural meeting in this state by a farmer present who had had much experience in feeding dairy cows (to the effect) that he did not consider the butts of corn stalks to have any feeding value whatever,” led to a feeding trial at this Station¹ wherein the relative values of the “top” and the “butt” of the corn plant were measured, and wherein it was found that the cows did as well on one as on the other.

The corn harvester is the standard and most economical method of harvesting this crop wherever it is practicable to use it, and the more primitive corn knife whenever the operations are not extensive and the fields are small. Corn may be hand or machine cut; the former on small areas, or with lodged crops, the latter on larger farms or combinations of farms. In either case low down rack or low wheel wagons should be used in hauling. Formerly much whole, i. e. uncut, silage was stored. Nowadays the ubiquitous gasoline engine cuts it all.

¹Vt. Sta. Rpt. 3, pp. 68-69, (1889).

FILLING THE SILO

The writer does not care to express a choice as to cutters, but does stress the desirability of large capacity, lest the work drag and at some point should be blocked; also the advisability of securing a standard make in order that repairs may be obtained readily. Obviously the size of the silo, of the acreage to be cut, and of the available power will be considered in choosing a cutter. As between the chain carrier and the elevator and blower the advantage appears to be with the latter, which is disadvantaged only in that it takes more power to run it. A cutter and blower ordinarily will use to advantage power proportional to the length of the cutting cylinder, a horsepower to an inch. Half-inch pieces pack better than inch pieces and make better silage, but it costs more to cut them. In packing the silage, care must be taken to distribute the material, lest, owing to varying specific gravities, fragments of leaves and ears tend to separate mechanically. Various devices, a loose hanging board, a square or oblong box cover, canvas tubes, metal tubes, etc. are used as aids in mechanical distribution. They tend to lessen the labor of the man in the silo, who has plenty to do to keep the sides properly trodden. If the corn is overripe or unduly wilted before it is ensiled, and hence too dry, water may be added to lessen the likelihood of "fire fanging" or molding. It is well to wet the top of the silo anyhow as a means of air sealing it and in order to lessen the losses occasioned by spoiled silage. If silage is fed promptly, no other seal is needed; if not, a layer of wet sawdust serves the purpose; or one may sow oats on the top of the mass and wet it down, since a dense mat of sprouted oats forms an excellent cover. Thus handled, the loss from fermentation should not exceed 10 percent and may be considerably less.

COST OF SILO FILLING

Estimates of the cost of filling silos vary greatly. A study of this matter was made several years ago on 31 Wisconsin and Michigan farms which indicated that the costs ranged from 46 to 86 cents. Further studies on 87 farms in various sections placed the average figure at 87 cents, exclusive of interest and depreciation.¹ Similar studies as to the total cost of silage, including cost of growth and harvest, lead Woodward² to hold that from \$1.50 to \$4 per ton represent the limits of cost.

¹ U. S. Dept. Agr., Farmers' Bul. 578 (1915).

² Ibid.

A DAY'S WORK IN THE CORN FIELD

A recent bulletin¹ discusses a "normal day's work for various farm operations" and furnishes the following data concerning corn.

Planting	9½ hours,	one horse,	one man,	6¼ acres
Planting	9½ hours,	two horses,	one man,	8¼ acres
Planting	9½ hours,	two horses,	two men,	12¼ acres
		hand	hand	4 acres

"With an inexpensive hand planter a man can plant from 60 to 75 percent as much corn as can be done with a man and one horse, using the horse-drawn type of implement."

Cultivating 9½ hours, one horse	4.3 acres
Cultivating 9½ hours, two horses	7 acres

Harvesting: Binder	1 to 40 bushels	41 to 60 bushels	More than 60 bushels
Harvesting: Using two horses..	7.5 acres	6.7 acres	5.6 acres
Harvesting: Using three horses	7.6 acres	7.2 acres	6.3 acres
Harvesting: Using four horses.	8.2 acres	8.3 acres	7.2 acres

Harvesting: Platform cutter—Two men, 1 horse.....	4.6 acres
Two men, 2 horses.....	5.2 acres
Three men, 1 horse.....	5.9 acres
Three men, 2 horses.....	6.8 acres
Four men, 1 horse.....	8.2 acres
Four men, 2 horses.....	10 acres

	1 to 40 bushels	41 to 60 bushels	More than 60 bushels
Cutting, shocking and hand tying	1.7 acres	1.5 acres	1.4 acres
Tying and shocking after binder	4.7 acres	3.7 acres	3.2 acres
Husking from stook.....	35 bushels	42 bushels	50 bushels

"A reasonable figure for the duty per horse in this operation is from 2 to 2.5 acres per day."

"The average acreage per man is 2.93 and per horse 4.17 acres."

COST OF CORN HARVEST

Extensive studies of the cost of corn harvesting operations made some 10 years ago² indicate that an average man can hand cut and stook 1½ acres at a cost of \$1.50 per acre; that the sled harvester type of mechanism averages to cut an acre at \$1.18, two men, a horse and a sled harvester cutting 4⅔ acres as compared with 3 acres cut by two men by hand or 1⅓ acres to the credit of the horse and machine; and that the corn harvester and binder of 10 years ago with three horses cuts 7¼ acres daily, that its average life is 8½ years or, in terms of acres cut, 668¾ acres; that it costs to cut an acre \$1.50 if the corn is shocked, divided as follows; depreciation, repairs, interest, etc. 29

¹ U. S. Dept. Agr., Bul. 3 (1915).

² U. S. Dept. Agr., Of. Exp. Sta., Bul. 173 (1907); also, U. S. Dept. Agr., Farmers' Bul. 303 (1907).

cents, drivers and team 46 cents, twine 31 cents, shocking 45 cents. The harvester doubtless cuts less than this when the bundles are at once thrown on the wagon for transportation to the silage cutter. Zintheo says in this connection¹ that "if a man has only 20 acres of corn to cut per year the cost for the use of the binder for each year would be \$15.30. To this should be added \$7.20 for interest, making the total annual cost of the machine \$22.50. Other expenses for cutting the 20 acres of corn, according to the previous averages derived, would be \$9.20 for team and driver, \$6.10 for twine and \$8.96 for shockers; or a total cost for cutting 20 acres of corn with a corn binder of \$46.76, or \$2.34 per acre. We have seen that the work may be done by hand for \$1.50 per acre and that by hiring a neighbor's team and binder at 75 cents per acre the work also may be done for \$1.50 per acre. We may conclude then that a farmer who has only 20 acres of corn to cut per year, and does not intend to cut any for his neighbors, would lose money by purchasing a corn binder.

"If a farmer has 30 acres of corn to cut per year the annual cost of the machine, including interest, would be 75 cents per acre. It will require a cut of at least 80 acres per year before the farmer can properly estimate the cost per acre for the use of the machine to 29 cents, as already given. It may, therefore, be concluded as a general proposition that unless this number of acres is available for cutting each year the investment in a corn binder is not profitable.

"These estimates may not be exactly fair, because if the corn binder cuts but 20 acres per year the life of the machine with proper care probably would be considerably longer than eight years. There is no doubt that, in general, half the money spent for implements could be saved if they were given better care when in use and when not in use protected in an implement shed from wind, rain, sunshine, and farm animals. In general it is wise not to invest in expensive implements unless there is sufficient work in sight to make them profitable."

SILOS

The first American silo was an eight-foot deep pit dug in East Lansing, Mich., in 1875. The first silo in New England was built in Billerica, Mass., in 1879. The writer, then a student at the Massachusetts Agricultural College, was told by his instructor, as was the rest of the class, about this remarkable and new method of preserving corn. It was expected that the entire class would go to Billerica to see the

¹U. S. Dept. Agr., *Farmers' Bul.* 303, pp. 29-30 (1907).

marvel; but we did not go. All the earlier silos were dug into the ground; all those constructed today are above the ground. There are many sorts of silos built nowadays, but practically all now being constructed are round and in this wooded country are generally made of staves, with concrete a distant second.

Stave silos are cheap, easily built and quickly put together. They are, furthermore, to be bought "ready made." They are the most common type now extant. Their faults are that they do not last many years and that, if not carefully erected, they may blow or fall down or get "whopper-jawed" on their foundations.

Concrete silos are more costly and more difficult to erect than are stave silos. Once built, however, they last forever and neither rot out nor blow down; nor are repair bills to be faced. Other forms, the so-called "Wisconsin," "Gurler," "Iowa," etc., are also built.

Whatever its construction, whether of wood or of concrete, the silo must be air-tight, smooth-walled and deep and should be round. Silage losses due to fermentation and decay are minimized by the exclusion of air, since the bacteria, yeasts and molds which cause these losses thrive in the presence of and die in the absence of air. Well matured lumber or cement washes or concrete should be used to this end, and smooth and plumb walls are necessary for the same reason. And, yet again, depth conduces to air exclusion since the superincumbent pressure is increased. And, finally, there are no corners in a round silo, the walls are stronger and the capacity greater in proportion to material and cost.

One who contemplates building a silo considers not only the material but also its location and size. A silo nowadays rarely is constructed within the barn, but is placed outside and "close handy by," a few feet from and opening into the barn, or, better, into a separate but adjacent room, thus minimizing the effect of silage odors at milking. The size of the silo depends on local circumstances, the lay of the land, the size of the herd, etc. It should be so planned that the feeding level may drop from 1.5 to 3 inches daily, the lower figure in the winter and the upper figure in the summer season. Since most of the losses occur on or near the surface, its constant renewal through usage tends to lessen loss. Better a stove-pipe sort of silo than one of the wash-tub variety. If one knows fairly well in advance how large a herd is to be fed, the type of cows, whether hearty or dainty eaters, the acreage which will be planted year after year with corn, one can calculate silo dimensions fairly well. Obviously the deeper

the silo the more compact the silage and the greater its diameter, the larger its capacity. Its contents in terms of tons of silage are a factor of depth and diameter. The former should not be less than twice nor more than thrice its diameter. The following tables¹ show in succinct form the relation of the size of the herd to silo diameters for winter and for summer feeding as well as the depth of silage for given capacities and diameters. In calculating one should allow 25 to 30 pounds daily for a 900 pound cow or steer; 35 to 40 pounds daily for a 1200 pound cow or steer; not more than half as much for yearlings or for horses; and an eighth as much for a sheep.

Relation of size of herd to diameter of silo for winter feeding (on basis of 40 pounds of silage per cubic foot).

Inside diameter of silo feet	Quantity of silage in depth of 2 inches pounds	Number of animals that may be fed allowing—			
		40 pounds per head	30 pounds per head	20 pounds per head	15 pounds per head
10	524	13	17	26	35
11	634	16	21	31	42
12	754	19	25	37	50
13	885	22	29	44	59
14	1,026	25	34	51	68
15	1,178	29	39	59	78
16	1,340	33	44	67	89
17	1,513	38	50	75	101
18	1,696	42	56	85	113
20	2,094	52	70	104	139

Relation of size of herd to diameter of silo for summer feeding (on basis of 40 pounds of silage per cubic foot).

Inside diameter of silo feet	Quantity of silage in depth of 3 inches pounds	Number of animals that may be fed allowing—			
		40 pounds per head	30 pounds per head	20 pounds per head	15 pounds per head
10	785	19	26	39	52
11	950	23	31	47	63
12	1,131	28	37	56	75
13	1,327	33	44	66	88
14	1,539	38	51	77	102
15	1,767	44	59	88	118
16	2,011	50	67	100	134

¹ U. S. Dept. Agr., Farmers' Bul. 589 (1914).

DEPTH OF SILAGE (AFTER SETTLING) FOR A GIVEN CAPACITY OF SILO WITH A GIVEN DIAMETER¹

Depth of silage (after settling)	10 feet	11 feet	12 feet	13 feet	14 feet	15 feet	16 feet	17 feet	18 feet	20 feet
Feet	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
24	34									
26	38	46	55							
28	42	51	61	71	83					
30	47	56	67	79	91	105				
32		62	74	86	100	115	131			
34			80	94	109	126	143	161		
36			87	102	119	136	155	175	196	
38				110	128	147	167	189	212	261
40					138	158	180	203	228	281
42						170	193	218	245	302
44							207	234	262	323
46								250	280	345
48										368

Vermont farmers who contemplate silo building will do well to secure Farmers' Bulletin 589 on "home-made silos," writing their congressman or senator. It is free for the asking. At length and painstakingly it goes into the details of silo construction, concrete, stave and "Wisconsin." Illustrations, plans, etc., make the matter clear. Furthermore, the Dairy Division of the Bureau of Animal Industry of the United States Department of Agriculture stands ready on request and without charge to send to any Vermont farmer who may wish to know what materials he needs and how much of each kind, a complete list thereof, if he on his part will state the size and kind of silo he contemplates building. In view of the fact that this excellent treatise is thus freely available, there seems now no need of going into details touching silo building in this bulletin.

CONCERNING STOOKING, HUSKING AND CRIBBING CORN

On farms where for any reason silos seem impracticable, it is common practice to stook or shock the crop at harvest time. An erect, well made stook which keeps its contents dry is the desideratum. Yet how many twisted and fallen stooks one sees, what lamentable wastage, indicative either of carelessness or ignorance. A slight slant, prompt tying two feet or thereabouts below the top, followed later, by tightening, large stooks made of 14 to 18 hills in dry and cool fall climates, and of 8 to 10 hills in moist and warmer fall climates, husking when well cured, the stover being placed in large stooks or in a mow in the barn; these are the essentials.

¹ These figures were taken in part from King's *Physics of Agriculture*, page 424.

Husking and shredding mechanisms rarely are used in Vermont. Farmers willing to make the necessary investment naturally and properly prefer to buy mechanisms which will enable them to ensile their crop.

The corn crib is seen less commonly in Vermont than in former times, but of course is common in non-dairy sections. In case one now seeks to build a crib, adequate ventilation, protection against storm, ease of filling and emptying, protection against vermin, birds and insects are essential. Crib shrinkage is a variable factor, depending on the moisture content of the corn when harvested and the circulation of the air through the crib. A series of trials made in the corn belt states with dent corn indicated an average of $14\frac{1}{2}$ percent shrinkage from December to June with extremes of 8 and 18 percents and in two years an average shrinkage of 20 percent. The usual legal weight of a bushel of corn is 70 pounds of ears and 56 pounds of shelled corn.

COST OF GROWING CORN

What does it cost to grow corn? Statistics gathered in 1909 from about 6,000 correspondents of the Federal Department of Agriculture indicated that it cost \$12.27 per acre.¹ In the North Atlantic States, however, it costs much more than elsewhere, \$20.44, but the acre value of the corn was far in excess of that secured elsewhere, \$30.17; a difference of \$9.73, a gain which was greater absolutely though not relatively than that obtained in any other section.

THE JUDGING OF CORN

Of late years corn judging has enjoyed considerable vogue. There have been misunderstandings about the proposition; people have thought that the prize ear if used as seed would grow a prize crop, forgetting that there were many things other than seed necessary to the growth of a good crop, and that the best seed sown at a latitude to which it is ill adapted does not do well. It is somewhat the same proposition as obtains in stock judging. It does not always follow that the Jersey cow which most nearly meets the ideals of grace, beauty, contour, color, etc., yields as much milk and butter as does her homelier sister. "Handsome is that handsome does" in cows, in corn and in human creatures. The boom, however, seems to be subsiding; less is heard today of \$1,000 ears than formerly; and corn judging and corn shows are be-

¹U. S. Dept. Agr., Bu. Statls., Crop Rpt., Apr., 1911.

coming less of a brass band affair and more of a business matter. Corn shows are worth while as a means of focusing public attention upon this important crop, as a propaganda measure; and corn judging is worth while as a means of educating corn growers touching standards and of inspiring them the better to care for their crops.

Soundness, maturity, symmetry, uniformity and beauty are the points usually considered in formulating a score card. The shape and size of the ears, the uniformity of the rows of kernels, the manner in which the butts and tips of the ear are filled out and the type of kernels are taken into consideration.

The following score card is the one suggested in a recent Farmers' Bulletin on "School Lessons on Corn:"

SCORE CARD FOR CORN

1. Trueness to type	10
2. Shape of ear	10
3. Purity of color in grain and cob	5
4. Vitality, maturity, germinating power	20
5. Tips of ears	5
6. Butts of ears	5
7. Uniformity of kernels	5
8. Shape of kernels	5
9. Length of ear	5
10. Circumference of ear	5
11. Furrows between rows	5
12. Space between kernels at cob	10
13. Proportion of corn to cob	10
Total	100

SCHOOL LESSONS

Farmers' Bulletin 617 entitled "School Lessons on Corn" should be used in every rural school. It suggests queries as to the kinds of corn, the color, location in the kernels, number of rows, kernels, etc., the embryo and its food, depth of planting, how and when to plant, culture, study of growth, of the roots, leaves, stalks, flowers, ears and pests, the gathering and storing of seed, feeding value and importance of the crop and its history. It contains exercises on seed corn selection, judging corn, testing for viability, selecting for exhibition and cultivation and breeding, and, finally, lists a considerable number of federal bulletins on corn.

Teachers and union superintendents can secure this bulletin for school uses through either senator or representative or direct from the Division of Publications, United States Department of Agriculture, Washington, D. C.

4. FEEDING

Corn in one form or another is eaten and drunk by all sorts and conditions of men and by almost all sorts and conditions of beasts; the grain by the one, the whole plant or some separate portion thereof by the other. It enters into the dietary of every race. Every animal listed in volume III of Bailey's *Cyclopedia of American Agriculture* can eat, digest and profit by this wonderful crop, save perhaps the fish, frog, silkworm, sponge and turtle; and the writer is not sure but that some of these can eat corn.

Corn makes up a large part of our various rations and in a multiplicity of ways. It is eaten, drunk and smoked; used as a staple and as a luxury. We sleep upon it, feed upon it and some of our garments are starched therewith. It is the greatest of our crops, not only in terms of acreage and volume but in respect to its manifold usefulness. What other crop is used in such a variety of ways? From what other crop may be made the explosive wherewith to launch the projectile at a superdreadnaught and also the protective armor wherewith to repair the damage wrought by the projectile? What other crop furnishes the pipe wherein and the corn silk wherewith to smoke in our boyhood days? What other crop furnishes both the staple food and its sweetening, corn meal and glucose? What other crop will at once warm the inebriate's body internally in the form of whiskey and externally, as in the West, where the ears are sometimes burned as fuel? Corn is not only king, but queen, jack and all the rest of the pack save the ace, which is alfalfa.

COMPOSITION OF CORN

A mature corn plant, ready for the silo, contains from two-thirds to three-fourths its weight of water. In mid-July it contains nine-tenths its weight of water, and when at the roasting stage, four-fifths its weight of water. The non-watery portions, the so-called "dry matter," is made up of somewhat less than one-tenth part ash and somewhat more than nine-tenths parts of organic matter, material which will burn. The water and the ash are soil-derived, the organic matter is in part soil—but largely air-derived. The organic matter consists of protein, the nutrient especially concerned in flesh formation, crude fiber, the frame work ingredient of the plant, so to speak, starches, sugars, and kindred bodies—grouped by the chemist under the general and unhappy term "nitrogen-free extract"—and the so-

called "ether extract," a mixture of fats, resins, chlorophyll, etc. The proportions vary as the plant matures. Relatively it analyzes lower in ash, protein and fat and higher in fiber, starches and sugars as maturity advances. It is most watery in early life and least watery in late life.

The maize plant is separable into many parts; the ear from the stover, the kernel from the ear, the so-called "corn bran" from the kernel. These divers parts differ somewhat in digestibility and in their adaptations to special uses. These differences, however, are less extreme than those found with some other economic plants.

The following analytical data, drawn from bulletin 152 (which deals with the "principles and practice of stock feeding" and which is free for the asking) set forth the composition and digestible nutrients of the corn plant and its principal separates:

COMPOSITION OF THE CORN PLANT

Material	Number of analyses	Food constituents						Fertilizing constituents			
		Water	Crude ash	Crude protein	Crude fiber	Nitrogen-free extract	Ether extract	Nitrogen	Phosphoric acid	Potash	
		%	%	%	%	%	%	%	%	%	
Green fodder corn.....	126	79.3	1.2	1.8	5.0	12.2	0.5	0.41	0.15	0.33	
Green dent corn.....	63	79.0	1.2	1.7	5.6	12.0	0.5	...	...	...	
Green dent corn (kernels glazed)....	7	73.4	1.5	2.0	6.7	15.5	0.9	...	...	...	
Green flint corn.....	40	79.8	1.1	2.0	4.3	12.1	0.7	...	...	...	
Green flint corn (kernels glazed)....	10	77.1	1.1	2.7	4.3	14.6	0.8	...	...	...	
Green sweet corn.....	21	79.1	1.3	1.9	4.4	12.8	0.5	...	...	...	
Corn fodder (field cured).....	35	42.2	2.7	4.5	14.3	34.7	1.6	1.76	0.54	0.89	
Corn stover (field cured).....	60	40.1	3.4	3.8	19.8	31.8	1.1	1.04	0.29	1.40	
Corn silage (mature corn).....	49	73.7	1.6	2.2	6.5	15.1	0.9	0.35	0.10	0.40	
Corn silage (immature corn).....	99	79.1	1.4	1.7	6.0	11.0	0.8	0.27	0.11	0.37	
Corn stover silage.....	6	80.7	1.8	1.8	5.6	9.5	0.6	0.29	0.11	0.45	
Corn and soy bean silage.....	4	76.0	2.4	2.5	7.2	11.1	0.8	0.65	0.35	0.36	
Corn meal.....	77	15.0	1.4	9.2	1.9	68.7	3.8	1.47	0.63	0.40	
Corn and cob meal.....	7	15.1	1.5	8.5	6.6	64.8	3.5	1.41	0.57	0.47	
Corn (dent).....	86	10.6	1.5	10.3	2.2	70.4	5.0	1.65	...	...	
Corn (flint).....	68	11.3	1.4	10.5	1.7	70.1	5.0	1.68	...	...	
Corn (sweet).....	26	8.8	1.9	11.6	2.8	66.8	8.1	1.86	...	...	
Corn cobs.....	18	10.7	1.4	2.4	30.1	54.9	0.5	...	...	...	
Corn bran.....	5	9.1	1.3	9.0	12.7	62.2	5.8	1.63	1.21	0.68	

Material	Digestible nutrients						Nutritive ratio
	Dry matter	Crude protein	Crude fiber	Nitrogen-free extract	Ether extract	Total digestible carbohydrates	
	%	%	%	%	%	%	
Green dent corn (immature)	14.3	1.1	3.8	8.5	0.3	13.0	1: 11.8
Green dent corn (kernels glazed)	18.1	1.1	3.8	11.3	0.7	16.7	1: 15.2
Green flint corn	13.9	1.0	3.3	8.6	0.5	13.0	1: 13.
Green flint corn (kernels glazed)	15.8	1.4	3.2	10.4	0.5	14.7	1: 10.5
Sweet corn	16.	1.2	2.6	9.9	0.4	13.4	1: 11.2
Corn fodder (field cured)	39.3	2.5	8.0	25.0	1.2	35.7	1: 14.3
Corn stover (field cured)	34.2	1.4	12.7	18.8	0.7	33.1	1: 23.6
Corn silage (mature corn)	17.4	1.1	4.2	10.7	0.7	16.5	1: 15.
Corn silage (immature corn)	13.4	0.9	4.1	7.3	0.6	12.8	1: 14.2
Corn stover silage	11.	0.6	3.6	5.5	0.4	10.	1: 16.7
Corn and soy bean silage	16.6	1.6	4.5	8.7	0.7	14.8	1: 9.3
Corn meal	74.8	6.1	..	63.2	3.5	71.1	1: 11.7
Corn and cob meal	67.1	4.4	3.0	57.	2.9	66.5	1: 15.1
Corn (dent)	81.3	7.8	1.3	65.5	4.3	76.5	1: 9.8
Corn (flint)	80.7	8.	1.0	65.2	4.3	74.9	1: 9.4
Corn (sweet)	83.	8.8	1.6	62.1	7.0	79.4	1: 9.0
Corn cobs	54.3	0.5	20.3	33.7	0.3	54.7	1:109.4
Corn bran	63.6	4.9	7.5	47.9	4.5	65.5	1: 13.4

The several separates do not differ widely on the dry matter basis, that is to say, when all water is eliminated. The divergencies are found to be within the following limits: Crude ash, 2 to 9 percent; crude protein, 6 to 11 percent; crude fat, $1\frac{1}{2}$ to 5 percent; nitrogen-free extract and crude fiber, 76 to 87 percent. As already remarked, these figures really are not very widely variant. They illustrate the well understood fact that neither the corn plant nor any of its separates is of a distinctively protein character. The particular service of the corn plant in the feeding of human or brute creation is this, that it furnishes large amounts of relatively inexpensive digestible carbohydrates—starches and the like. One must turn elsewhere, be he two-legged or four-legged, human or brute, if he seeks relatively large amounts of digestible proteids.

The entire corn plant, except its roots, is available as food for domestic animals. That cattle will eat it all—stalk, leaf, tassel, ear—is well understood. That work horses, particularly such as are being wintered without heavy labor, will thrive thereon is less well understood. That sheep and even swine may eat the entire plant to advantage, has not been as well understood. Indeed, the writer has heard it stated in all seriousness that there is not a single domestic animal upon the farm which may not eat silage to advantage—except the hired girl.

The place of the corn plant in milk making hardly needs advertising. "Good wine needs no bush." In a section in which dairying obtains to such an extent as in New England, where the yield outranks those of other sections, where silos abound and the cow population is relatively dense; to point out in such a region and to such a people the paramountcy of corn seems unnecessary. Yet the fact that New England leads in the production of bushels per acre does not mean that she leads in her production of bushels per unit of arable area as compared with other states. She grows more corn than her sisters—where she grows it—but she does not grow enough. Her farmers still fail adequately to appreciate three vital matters in connection with corn growing, viz.:

1. The advisability of growing more corn per cow.
2. The advisability of growing more digestible dry matter per unit of area and per unit of effort.
3. The advisability of placing in the cows' mangers 90 to 95 percent of the digestible dry matter which is harvested rather than the 60 to 85 percent often placed there.

A few words as to each of these propositions:

1. *The advisability of growing more corn per cow.* It is generally conceded that under most conditions of New England soils, climate and environment in those sections where dairying obtains, corn furnishes cheaper digestible carbohydrates than does any other roughage. A cow needs from $1\frac{1}{2}$ to 2 or more pounds of digestible protein daily to enable her to make milk economically; but she needs at the same time 12 or more pounds daily of digestible carbohydrates. It is well understood that the latter is the cheaper nutrient, but it is just as necessary as is the more expensive one. Corn solves the New England carbohydrate problem. In portions of the Champlain valley, in the Aroostook region of Maine, perhaps in some sections of the Berkshires and in the higher Green and White Mountain regions, either soil or climatic conditions or both are such as often to make grass a more economical source of digestible carbohydrates than corn; but such a situation is exceptional and does not represent New England as a whole.

2. *The advisability of growing more digestible dry matter per unit of area and effort.* Tillage, drainage, fertilization, good seed, etc., have been hitherto reviewed as well as the need of making a wise varietal choice. Probably it is safe to say that there are over a thousand varieties of corn listed in seed dealers' catalogues. No one of these necessarily is the best. Certainly no one of them is the best throughout New England or throughout the country. In answer to that frequent question, "What is the best variety for me to grow?" the writer believes—as has been said already—that one should advise the choice of that variety which will produce the most digestible dry matter to the acre, so be it that the crop is likely under the conditions of a normal season to become mature or almost mature before killing frosts occur. Weather vagaries are such as to make the choice which is best one year not the best choice another year. Hence it is wise usually to plant the variety that will meet the conditions of a normal season. It is particularly unwise to attempt to grow a variety fitted for latitudes further south, since maturity rarely can be attained. The impressive growth is largely water.

The writer cannot forbear citing at this point in the discussion an experience met at this Station some 15 years ago. A western institute speaker went up and down the state urging his hearers to plant a certain southern corn on the ground that it had matured with him the previous year and had made a large growth. The writer and others to the manner born felt that the advice was un-

wise, but the popularity and persuasive ways of the lecturer were such that many Vermont farmers planted this variety. The season was an average one and the corn grew well. The station plots attracted much attention. They were located along the highway and many people stopped at the farm superintendent's house, asked where he got that seed and vowed that they were going to grow that corn next year. However, the Station was in a better position than were most people to judge as to its real value. The crop was harvested quite late, because corn can be cut in the Champlain valley somewhat later than in many parts of northern Vermont. Indeed in this particular year we did not start harvesting corn until after the first of October and finished filling the silos about October 15th. The Sanford corn was mature, the southern corn, immature, its ears just beginning to fill out. There was 60 percent more green weight in the southern corn than in the Sanford corn; but that extra 60 percent was almost entirely water. For every 100 pounds of dry matter in the Sanford corn were harvested 101 pounds in the southern corn. In other words, practically no more food was secured in the one case than in the other; and we had the fun of cutting, hauling, handling and giving silo room to 59 extra pounds of water in order that we might get one extra pound of food matter. Furthermore, the silage made from this immature corn, as compared with that made from Sanford corn, was relatively sour and less serviceable. When the cows were changed from the Sanford silage to this southern corn silage, pound for pound being fed, they shrank decidedly and in order to maintain the milk flow we had to feed from 60 to 65 percent more of the dilute silage than of the regular silage.

3. *The advisability of getting more of the total dry matter harvested before the cows.* There is but one commandment to be urged here; to ensile the entire crop in a modern silo. Twenty-five years ago there was a good deal of doubt in farmers' minds as to silos and silage. Fifteen years ago many were still unconverted. Today there are practically no doubting Thomases. Time was when condensed milk factories would not take silage milk. Indeed, it is only recently that some of them have come into line. Now the use of silage has become almost universal in Vermont. The county agent of one of our best east-side counties states that 75 percent of its farmers have silos. The din of the old-time battles has ceased. The healthfulness of silage, its relation to tuberculosis and abortion, its effect on cows' teeth, on the souring of milk, on the taste of the milk, on its effect on the quality

and serviceability of baby milk are not now live issues. Few persons now question whether it does or does not pay to pluck the ears, a burning question 20 years ago. Nor is there nowadays as much following after strange gods in the form of great ensilage corns which do not mature. The Vermont farmer now seeks to grow a heavily eared corn in order to lessen his grain bills, gathers his crop with a corn harvester, cuts and blows it, ears and all, into his stave silo, and feeds silage for from 7 to 12 months yearly. He has accepted fully the dictum that more milk and butter grow on an acre if the corn is mature than if it is immature; that there are better and cheaper ways of watering cows than by growing large varieties which do not mature; that the last month's growth nearly or quite doubles the food value of the crop; that somewhat hard and well glazed kernels and partially dried husks are the tell-tales as to the proper time to harvest, a condition which ordinarily lasts for a week or ten days; that when in this condition the stalks contain enough moisture to pack well; that it is better to run the risk of over-ripeness and frost, and to add water if necessary to the silage, than to cut too green; that it costs more in the long run to stook and to feed from the stook than to ensile and to feed from the silo; that losses from mice, drying out, molding, etc., in the stook exceed those occurring in a good silo; that grinding corn does not increase its food value; and he profits by his understanding.

Palatable, succulent, healthful, nutritious, economical, silage is the mainstay of modern dairying in regions where corn thrives, and is outclassed only by alfalfa hay in regions where this wonderful crop grows best.

The fundamental reason why the silo has come to its own in New England is simply this: That a larger proportion of the total digestible dry matter harvested, by means of the silo can be placed before the cows than when the crop is preserved in any other form; that a food unit can be placed in a cow's manger cheaper than via the corn stook; that, moreover, its succulence fits it particularly for milk making; that it usually furnishes the cheapest summer soiling. Moreover, it is understood fully, now, that nothing is to be gained by husking the corn prior to putting it in the silo. This verdict was rendered by a multitude of cows at the Wisconsin station, at the Vermont station, and at one or two other points.

ADAPTATION OF SILAGE TO THE USES OF VARIOUS FARM ANIMALS

Dairy cattle. Cows. Silage is an admirable feed for dairy cattle but does not constitute a complete ration. It is lacking relatively in protein and ash contents and should be supplemented with rich hay (clover, alfalfa, early cut grasses) and grain. The amount to be fed depends upon the individual cow's assimilative capacity, varying from 25 to 45 pounds daily, whatever will be eaten without waste. Preferably, but not necessarily, silage should be fed at some time before milking, and usually twice daily. Fed during or shortly before milking possibly it may convey a slight taste into the milk; but if the barn is well ventilated and the silage not very odoriferous one may not feel obligated to obey this law literally.

Bull. Liberal silage rations are not thought desirable by most breeders. A 10 to 15 pound ration to a 1,000 pound live weight should suffice.

Calves may be fed silage as soon as they can consume solid food, as much as they will eat up clean. Yearlings will eat half as much as mature cows.

Beef cattle. Silage is of much service here. Grain bills are reduced and beef is made more cheaply. A breeding herd may be wintered on it to advantage if a good grade of hay also is fed. Over-feeding with silage tends to loosen the bowels, yet on the other hand, thin cattle often have used a straight corn silage ration to advantage. It is well adapted to the "finishing" process, particularly in view of the high cost of concentrates and of hay. Indeed, it may well be the mainstay under such circumstances. Ward¹ suggests corn silage 30 pounds, corn stover 6 pounds, shelled corn 10 pounds, and cottonseed or linseed meal 4 pounds, per 1,000 pounds of steer. Silage tends to produce a high grade of finish both as regards gains, external appearance (coat) and internal appearance (grade of carcass). In fact the corn plant in any form, silage, stover, grain, is especially adapted to the rounding out of the mature carcass.

Horses. The horse's digestive tract is quite unlike that of the bovine. According to the way we view it, he is blessed or cursed with but one stomach instead of four. His stomatic capacity is so much less and its peculiar construction as regards the possibility of regurgitation is such, that he cannot consume large amounts of food at any one time. In particular the taking into the stomach of large

¹U. S. Dept. Agr., Farmers' Bul. 578 (1914).

amounts of a fermentable food, is, as the physicians would say, counter-indicated. Hence silage, a dilute and a fermentable food, is not used to any large extent. Indeed it may become a dangerous feed, particularly if moldy, since many molds are poisonous to horses; or if frozen, lest it induce colic; or if made from immature corn, or if very sour, lest it cause colic. Summer silage is so much more apt to become moldy than winter silage that it is rarely safe to use it at this season. Its best service is found in wintering idle horses or brood mares, although corn fodder is likely to be better fitted to this purpose. It is not adapted to the use of hard working horses. There is a general notion abroad that silage tends to make a somewhat soft and watery flesh, a notion which is strongly combated by some who believe it well adapted, particularly to the growing of colts.

What happens when silage is made? What changes take place? Prolonged investigations carried on at the Wisconsin station have answered these questions quite satisfactorily. It is generally known that cut silage "heats," becomes more or less acid and somewhat aromatic, assuming a brownish tinge. Under normal conditions the biological agents producing the chemical changes which occur in silage making are the respiratory processes of the plant tissues, enzymes which are inherent therein, and micro-organisms which are carried mechanically into the silo with the cut silage. The initial "heating" which is characteristic of silage making is due mainly to these respiratory processes, to the breathing—to speak in general terms—of the cells of the plant tissues. The production of acid and the extent of such production seems to be brought about by the same processes. Putrefactive changes are wrought by anaerobic (air-shunning) bacteria. The development of aromas seems associated with, if not caused by, enzymic activities; all of which is equivalent to saying that the normal changes which make silage different from the corn from which it is made, are brought about by the internal processes, the normal functions of the cut tissues of the corn plant.

This breathing process is a destructive one. The more it is retarded and the quicker the cut tissues die, the less the loss incident to the ensiling process. Some loss is inevitable. It may be—it rarely is—as low as 1½ percent, it may be as high as 25 percent or more. The unavoidable losses are of water, carbon dioxid (carbonic acid gas), and volatile organic acids, which are the results of the respiration. The avoidable losses are putrefactive and fermentative in character and are due to bacteria and molds, the growth of which is greatly favored

by the admission of air when silos are poorly built or silage is improperly packed. All the organic constituents suffer, although the crude fiber and fat are not materially affected. The sugar is almost entirely eliminated and the protein to some extent converted into non-proteid forms.

It may be well to review briefly the use of this crop in forms other than silage in stock and human feeding.

Bovine. Cattle are fed for work, meat and milk. The fitness of corn as a food for the relatively slow moving ox is evident. Its fattening nature renders it inapplicable as a food for an animal from which high speed or a prompt manifestation of energy is desired. But for the patient ox, whose call upon his muscles is for slow, heavy, extreme exertion, this fattening material is ideal. This general proposition holds, whether the plant be fed as corn fodder, corn silage, ear corn or corn meal, except that there is a general feeling that when fed as silage it tends to make a relatively soft muscle structure.

When used for the making of beef the corn plant is better adapted to "finishing off" than it is to grow the animal. This limitation to its usefulness is readily understood when one bears in mind its chemical composition, particularly that of the ear, when one notes its relative lack of protein and of ash (see page 361). In the production of its skeletal and muscular structure the animal needs not starch but proteids, lime, phosphorus, etc. Hence corn is not well adapted to the making of a young animal. But fat is a product of starch, and consequently corn is fitted particularly for this purpose. It contains enough digestible protein to enable the animal to maintain its protein status so that its muscle structure will grow no less, and its heavy starch content enables the animal to round out its angles and thus to augment its sales and its food values. The ear, and more particularly the kernel, is adapted best and used most commonly for this purpose. In a celebrated feeding trial conducted some years ago at the Iowa station, wherein nearly 250 three-year old western cattle were fed, 93 cents a bushel was realized for corn, "a much higher price," the bulletin states, "than could have been realized from the same at any of the markets during the feeding period." Ninety-four days of feeding finished off the average steer with an average profit per animal of \$14.49. When corn brings but 40 cents per bushel and the beef sells at present prices, what more profitable use can be made of corn than to turn it into meat?

Dairy cattle. Since there is no second to silage and since silage is available to almost every dairyman except those who operate upon

a very small scale, it is hardly worth while to discuss at length the use of corn fodder, stover, etc. Suffice it to say that cows will make milk on it but to less advantage. Large stooks should be set up. If corn is thus stooked it is well to feed it relatively early in the season. "Many farmers are in the habit of saying that their cows do not like corn fodder after March 1. There is a good reason for it * * * it is not because the cattle are tired of corn fodder, but because the corn fodder has by this time largely lost its feeding value * * * There is a chemical depreciation in corn fodder * * * when it is exposed for any considerable time to the weather" (Wallace's Farmer). The loss is a two-fold one, a loss in palatability and actual food constituents wrought to chemical and biological changes, and a mechanical loss, due to the breaking off of leaves, the ravages of mice, etc. If the corn is stooked, inevitably there is a larger wastage of total dry matter to the acre than if it is ensiled, unless the silo is extremely old and out of repair. The fact is if the farmer fails to observe mold or rot in the stooks as he may in the silo, is not proof that no loss occurs.

Corn meal is well known to be good food for dairy cattle; but the question arises, why feed as meal instead of as silage? To separate the ear from the stalk for the cow whether ensiled or stooked is labor lost. The only excuse from the writer's point of view for feeding corn meal save in small quantities is the failure of the corn crop to mature. The writer can conceive of only one good reason for husking bees on dairy farms today, and that is the possibility of finding a red ear.

As between corn meal and corn and cob meal, a considerable amount of experimental feeding seems to favor the latter. It is thought to pack less closely in the stomach and intestines and to be permeated more readily by the digestive fluids than is corn meal. Furthermore, if finely ground it makes available an otherwise waste product, which does not possess high but does carry some food value. This fact does not constitute an argument for the adulteration of sales corn meal with ground corn cobs.

Horses. The corn kernel for horses is very well worth while under certain circumstances. This is fed ordinarily in the form of cracked corn. A considerable share of the grain ration of animals at hard work may be thus constituted. Corn is but ill adapted to the uses of livery or trotting horses, for its fattening qualities are such as to inhibit their active exercise. For slow, heavy work, however, if not

fed in immoderate quantities, it is well worth while, particularly in winter.

Sheep take kindly to the corn plant. It is not of course well adapted for the growth of the young lamb, but when lambs are to be fattened, either corn stover or the entire corn plant may be used to advantage. Even limited quantities of silage have been fed with satisfactory results though many have failed, owing to inferior material or to carelessness in feeding. Being relatively deficient in protein more concentrated grains must be used, such as linseed meal, cottonseed meal, or distillers' dried grains. The proportions best fitted for this purpose will depend naturally upon many conditions, including relative market prices. It is advised by some stock feeders that a high priced corn should be mixed approximately in the proportion of 4 to 1 with relatively low priced proteinous concentrates, or that, a low priced corn be mixed with high priced concentrates in the proportion of 9 to 1, the corn constituting 80 percent of the ration in one case and 90 percent in the other. However, with prices as they have ruled of late, when both corn and the proteinous concentrates sell at altitudinous prices, the carrying out of this dictum is difficult.

If silage is used it should be neither moldy, very sour nor frozen. Not to exceed from two or four pounds a day per animal should be fed. Its succulence is such that it acts as an appetizer, and the intestinal tract is kept in a healthy condition; but on the other hand, the material is so watery, relatively speaking, that sometimes it is difficult to get a lamb to take sufficient digestible dry matter to make a thoroughly satisfactory growth. If the silage is well eared, so much the better. It should not constitute more than half its ration. Feeding the uncut corn fodder from the feeding rack is an excellent way of feeding lambs. It is common in some sections to shred stover, which permits more thorough consumption and leaves the waste material in better shape for other purposes.

Swine. The corn plant is used very largely in this country, particularly the kernel, in the making of pork. The great American hog is commonly a corn fed animal. There are few of our domestic animals whose frame may be so profoundly modified by the character of the feeding as is that of the hog. Corn, because of its highly fattening qualities, tends to make an over-fat animal. Time was when the acme of perfection in porkdom was an animal so bulky that it was unable to stand. In later years little pigs rather than big ones have been the fashion. Now little pigs are not built readily from corn meal. This

material will build mountains of fat, but not active, muscular squealers. The pig, particularly in the earlier stages of his life, needs considerable amounts of digestible protein, more than is found in corn meal. A common and admirable New England mixture, less common today than formerly, was skim-milk and corn meal in varying proportions; relatively large amounts of dry matter from the skim-milk in the early stages of animal growth, relatively larger amounts of corn meal in the later stages of growth; while the final finishing off for the market was largely corn meal.

It is common practice in the West to turn the animals into a corn field from which the ears have been picked. They feed there upon the stalks and the poor corn left in the field. This practice is known as "hogging down" or "hogging off" corn. It is apt to be a wasteful procedure so far as food is concerned, but an economical one so far as human labor is concerned. Indeed, the tendency of late is to feel that in the end it is the best way for hogs to get corn and sometimes they are turned in before any ears have been harvested and allowed to help themselves. Some hog raisers believe that by thus helping themselves the animals help their masters better than by any other way of feeding.

One serious difficulty with the use of corn in the feeding of swine is its relative lack of ash constituents. Animals heavily fed with corn, having no access to dirt or ashes or other ash containing materials, often betray the serious lack of this ingredient by becoming lame. Their bones are small, brittle and ill adapted to hold up the excessive weight which heavy feeding entails.

However, when all is said and done, it seems likely that corn will continue for a long time to be sold largely in the form of pork and lard. While it may not make the highest grade of pork, it is well fitted for the making of those portions of the animal which are used for producing salt pork, lard, etc.

Whether the kernel should be ground or soaked or cooked is a moot point. Authorities differ. Some hold that the extra work on the part of the hog in crushing and masticating the kernels is more than made good by the more perfect digestion of the material thus mixed with the saliva. Others feel that grinding and soaking tend to promote digestibility. So far as cooking is concerned, it is understood fairly well that this in no way promotes digestibility.

Poultry. Corn is a favorite grain for poultry. Its bright color, its texture, its freedom from woody material, its considerable amounts of palatable fat and other ingredients, make it attractive both in point

of flavor and ease of digestion. Furthermore it meets the needs of appetite and serves market purposes as well. However, as with other animals, it is not well to feed with corn alone, or, indeed, to feed it largely. Its extremely fattening character is such that it is neither a perfect egg food nor the ideal food for the growing of the lean meat structure. Yet notwithstanding this fact, every hen, young or old, whether laying or not should receive corn with a fairly liberal hand. It is, of course, better fitted for those animals that are mature and fattening than for the youngsters that need to build muscle and skeleton structure. The cob is but ill adapted to poultry feeding and only the kernel should be used. Bulk for the ration should be furnished by materials like wheat bran, clover or alfalfa hay, rather than by the use of the cob. Hominy chop or meal, which likewise is a corn product, has been found very satisfactory for this purpose.

CORN CONCENTRATES

A few words concerning the corn concentrates. There appear to be several different kinds of corn meal on the market today: the old-fashioned meal made by the old-fashioned millers; the western corn meal from which more or less of the bran has been removed, together with a considerable portion of the chit or germ; and, perhaps some other brands which appear to be screenings from cracked corn. The differences in composition and service of these various meals are slight, save that the western corn meal carries a slightly lower fat content than does the old-fashioned meal. It is, however, on this account less likely to become rancid and as a commercial proposition it is to be preferred. Of course the chemical character of the kernel in no way is modified by the completeness of the subdivision of its particles. That is to say, whether fed whole, cracked, or ground, it is the same thing. However, it is well understood that a different physical character modifies its services for different purposes.

Hominy feed is a product of the making of an old-time breakfast food. It is not materially different in its character and chemical composition from corn meal, save that it contains rather more fat. It will be found serviceable in most places in lieu of corn meal in such times as it sells at a lower price. Its digestibility appears to be essentially the same.

The office of gluten feed and of distillers' dried grains in feeding is an important one. These products respectively of the manufacture of glucose and of Bourbon whiskey, because of their flaky character,

their high protein content, their palatability and their digestibility, their high digestible dry matter content and their relatively low cost, are most important additions to the dairyman's all too limited list of proteinous feeds. They are less dangerous when fed in quantity than are some of their competitors. Their effect upon the character of the products is good and it is to be hoped, viewing the matter solely from the standpoint of dairy feeding and shutting one's eyes entirely to ethics, that the wave of prohibition sentiments may not do away entirely with the use of corn in the manufacture of distillers' dried grains.

The writer makes no attempt to indicate the multitudinous uses in human feeding of this wonderful plant. Visions of the johnny-cakes and baked Indian puddings of his boyhood float before his eyes. The winter Sunday evening popcorn meal of his later years, the cup which cheers and inebriates (concerning which he has no personal recollections), the sweet corn ungracefully gnawed from the cob or canned in Vermont and sold as Maine sweet corn, the hoe cake and hominy of southern lands, the hasty pudding, the mush and milk of earlier days and the myriad corn breakfast foods of today; to name these does not begin to catalogue the uses of corn for human food. Paraphrasing, quite without irreverent intent, the Moslem's creed, "There is no god but God and Mahomet is his prophet," we may say, "There is no crop like maize and the American farmer gains the profit."

In the corn belt states considerations of marketing, market grades, export corn, etc. are of importance; but they cut no figure in Vermont except in so far as they influence the price of western corn and other concentrates; hence they are not discussed in this bulletin.

A LIST OF FEDERAL DEPARTMENT AND STATE STATION PUBLICATIONS DEALING WITH THE CORN CROP

Most, if not all, of the publications in this list (if in print) are to be had for the asking, addressing the Department of Agriculture, Washington, D. C., for its bulletins and the Experiment Station of the appropriate states for its bulletins. The following list shows the locations of the several stations.

The list is arranged in the order in which the various topics are discussed in the bulletins.

1. SEED

VARIETIES AND VARIETY TESTS

- Conn. (State) Sta. Rpts., 1893, 1913, Pt. 6.
 Jordan: Me. Sta. Rpt., 1889.
 Brooks: Mass. (Hatch) Sta. Rpts., 1896, 1897, 1901.
 Smith and Lindsey: Mass. Sta. Rpt., 1911.
 Minns: N. Y. (Cornell) Sta. Bul. 314 (1912).
 Flagg and Tucker: R. I. Sta. Rpt., 1895.
 Minott: Vt. Sta. Rpts., 1888, 1889, 1890.
 Hills: Vt. Sta. Rpts., 1893, 1903, Bul. 106 (1903).
 Emery: N. Y. (State) Sta. Rpt. 1889.
 Me. Sta. Rpt., 1891.
 Jordan: Me. Sta. Rpt., 1892, Bul. 17 (1893).
 Lindsey: Mass. Sta. Rpt., 1905.
 Whitche: N. H. Sta. Bul. 3 (1888).
 Ladd: N. Y. (State) Sta. Rpt., 1889.
 Cooke: Vt. Sta. Rpt., 1889.
 Roberts and Wing: N. Y. (Cornell) Sta. Bul. 16 (1890).
 Hughes: Silver King corn for northern Iowa. Iowa Sta. Bul. 138 (1913).
 Jordan: Southern vs. Maine field corn for silage. Me. Sta. Bul. 11 (1894).
 Sturtevant: Varieties of corn. U. S. Dept. Agr., Of. Exp. Sta., Bul. 57 (1899).
 Value of flint varieties of corn. U. S. Dept. of Agr., Farmers' Bul. 225 (1905).
 Briefed from Conn. (State) Sta. Bul. 147.
 Dent vs. flint varieties. Conn. (State) Sta. Rpt. 1889.

CORN BREEDING

- Collins: The importance of broad breeding in corn. U. S. Dept. Agr., Bu. Plant Ind., Bul. 141 (1909).
 Collins: Increased yields of corn from hybrid seed. U. S. Dept. Agr., Yearbook 1910, pp. 319-328.
 Hartley: Improvement of corn by seed selection. U. S. Dept. Agr., Yearbook 1902, pp. 539-552.
 Hartley: Cross breeding corn. U. S. Dept. Agr., Bu. Plant Ind., Bul. 218 (1912).
 Schulte: Corn breeding work at the experiment stations. U. S. Dept. Agr., Yearbook 1906, pp. 279-294.
 Ten generations of corn breeding. U. S. Dept. Agr., Farmers' Bul. 366 (1900).
 Briefed from Ill. Sta. Buls. 128, 132.
 Breeding corn of special composition. U. S. Dept. Agr., Farmers' Bul. 210 (1904). Briefed from Iowa Sta. Bul. 75.
 Breeding corn and the prevention of inbreeding. U. S. Dept. Agr., Farmers' Bul. 267 (1906). Briefed from Ill. Sta. Buls. 37, 100.
 Hayes: Corn breeding experiments. Conn. (State) Sta. Rpt., 1913, Pt. 6.
 Hayes: Inheritance in corn. Conn. (State) Sta. Rpt. 1911, Pt. 6.
 East and Hayes: Inheritance in corn. Conn. (State) Sta. Bul. 167 (1911).

SEED CORN

- Duvel: The germination of seed corn. U. S. Dept. Agr., Farmers' Bul. 253 (1906).
 Hartley: The production of good seed corn. U. S. Dept. Agr., Farmers' Bul. 229 (1905).
 Hartley: Seed corn. U. S. Dept. Agr., Farmers' Bul. 415 (1910).
 Hartley: The seed corn situation. U. S. Dept. Agr., Bu. Plant Ind., Circ. 95 (1912).
 Howe: How to test seed corn in school. U. S. Dept. Agr., Of. Exp. Sta., Circ. 96 (1910).
 Ear characteristics of seed corn. U. S. Dept. Agr., Farmers' Bul. 419 (1910).
 Briefed from Ohio Sta. Bul. 212; Ohio Sta. Circ. 71.
 Handling seed corn. U. S. Dept. Agr., Farmers' Bul. 244 (1906). Briefed from Iowa Sta. Bul. 77; Neb. Sta. Bul. 91.

- Selection of seed corn. U. S. Dept. Agr., Farmers' Bul. 193 (1904). Briefed from Ark. Sta. Bul. 51; Ill. Sta. Buls. 82, 87; Iowa Sta. Bul. 68; Mo. Sta. Bul. 59; N. D. Sta. Bul. 51; Ohio Sta. Bul. 140; N. C. Board of Agr. 24, No. 9; Univ. Tenn. Record 7, No. 1.
- Card, Sprague & Blake: Corn seed selection. R. I. Sta. Rpt., 1902; R. I. Sta. Rpt., 1905; R. I. Sta. Bul. 116 (1906); R. I. Sta. Rpt., 1907.
- Holden: Corn seed selection. Iowa Sta. Bul. 77 (1904).
- Pearl and Surface: Corn seed selection. Me. Sta. Bul. 183 (1910).
- Scofield. Commercial grading of corn. U. S. Dept. Agr., Bu. Plant Ind., Bul. 41 (1903).
- East: Corn improvement. Conn. (State) Sta. Bul. 152 (1906).
- Jeffrey: Corn improvement. Mich. Sta. Special Bul. 47 (1908).
- Smith: Corn improvement. Ill. Sta. Bul. 128 (1908).
- Wiancko: Corn improvement. Ind. Sta. Bul. 110 (1906).

2. SOIL

WEATHER

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BULLETIN No. 190

JUNE, 1915

Commercial Fertilizers Crop Rotation

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BULLETIN 190: COMMERCIAL FERTILIZERS

By J. L. HILLS, C. H. JONES, C. G. WILLIAMSON AND G. F. ANDERSON

CROP ROTATION

By R. T. BURDICK

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SUMMARY

III. Results of inspection. The Station has drawn from dealers' stocks and analyzed 173 licensed brands, the output of 19 companies, all this year's goods. All the licensed brands but six were sampled and analyzed.

1. Quantity of plant food. Eighty-three percent of the brands met their guaranties. Four brands failed to afford a commercial equivalent of the promises made for them. The outcome on the whole is a fairly satisfactory one.

2. Quality of plant food. The quality of the crude stock used seemed to be beyond reproach, save as regards the organic nitrogen in a few brands. Two brands carried potash mainly in the form of sulphate, in four brands half or less than half of the potash existed as sulphate, while in 167 brands it was found as muriate. One hundred and forty-three of the 162 nitrogen -- containing brands carried appreciable amounts of mineral as well as of organic forms of nitrogen, while 19 fertilizers carried less than 0.20 percent mineral nitrogen.

IV. Selling prices and valuations. The average selling price was \$33.06; the average valuation, \$20.64. One dollar in three spent for mixed fertilizers was paid to the manufacturer, railroad, and selling agent for their work, while but two of the three were paid for plant food. But 55 cents' worth of plant food was bought for a dollar in average low priced goods, and 63 cents' worth in medium priced goods. The average high priced brand, however, afforded 70 cents' worth for a dollar. Some Vermont buyers of mixed goods paid nearly twice as much for plant food as did others.

V. The analyses of the fertilizers sold in Vermont this year appear on pages 428-439.

VI. A comparison of analyses of brands for three years, hitherto made in the annual bulletin, is omitted because of the untoward conditions existing in the trade owing to the potash situation.

VII. A special article dealing with the principles and practice of crop rotation appears on pages 440-460.

II. INTRODUCTION.

The fertilizer law enacted in 1902 provides that the yearly bulletin of the Station dealing with commercial fertilizers not only shall furnish the results of the analyses of these goods, but also may afford "additional information in relation to [their] character, composition, value and use." It further directs that publication be made "as promptly as the progress of the analyses will allow and as frequently as time and means permit." The annual bulletin issued, if possible, early in the summer discloses the analyses of all the brands collected, shows their composition during the preceding two and the current years,¹ contains a general review of the state trade, makes statements as to the quantity and quality of the plant food sold in the various brands, considers the comparative value of the average goods of the current and preceding years, and outlines the relationship between selling prices and valuations.

These general matters are reviewed annually. In addition thereto there is presented yearly a somewhat full discussion of some special topic having to do with fertilization, a "feature" as it were. This plan was inaugurated in 1902, has been continued for more than a dozen years, and presumably will be pursued for several years to come. Thus the recipient of the bulletins who preserves them will in time possess a more or less complete treatise on the general subject of fertilization.

So far as possible technicalities have been, are and will be avoided and plain every-day language is used. Yet many who read will find that careful attention will be needed. For the assistance of such, glossaries of definitions were supplied in bulletins 99, 130, 143 and 154. Probably these glossaries will be added to from time to time in the future. Anyone failing to grasp the meaning of the terms used should get bulletins 99, 130, 143 or 154 (if in print) and make use of their glossaries. They are free for the asking. The annual fertilizer bulletin is always thoroughly indexed.

The following statement outlines the "features" of the preceding bulletins:

1902. Bulletin 93. *Formulas for home mixing*.—56 pages. (Out of print).

1903. Bulletin 99. *Vermont's usage of fertilizers. Concerning fertilizer buying. Deficient plant food*.—88 pages. (Out of print).

¹Omitted this year owing to the untoward conditions wrought by the European war, compelling manufacturers to cut their potash offerings to 4 percent or less.

1904. Bulletin 108. *Classification of commercial fertilizers sold in Vermont. Farm manures.*—68 pages. (Out of print).

1905. Bulletin 116. *How, when and what to use.*—104 pages. (Out of print).

1906. Bulletin 123. *Concerning the purchase of plant food. The moisture relations of the soil.*—68 pages. (Out of print).

1907. Bulletin 130. *Soil biology in its relation to fertilization.*—144 pages. (Out of print).

1908. Bulletin 135. *A quarter of a century of fertilizer inspection. Soil deterioration and soil humus.*—128 pages. (Out of print).

1909. Bulletin 143. *The service of a fertilizer control. Soil* pages.

1910. Bulletin 154. *Soil classifications and adaptations.*—112 *physiography.*—144 pages.

1911. Bulletin 160. *Limes and liming.*—144 pages.

1912. Bulletin 165. *A survey of the peat and muck deposits of Vermont.*—104 pages.

1913. Bulletin 173. *The principles of land drainage.*—96 pages.

1914. Bulletin 182. *Irrigation.*—104 pages.

These were written in 1902, 1903, 1904, 1905, 1906, 1907, 1908, 1909, 1910, 1911, 1912, 1913 and 1914; but they are quite as applicable to the purchase and use of fertilizers in 1915 and in succeeding years as they were when first penned. The reader of this bulletin who does not own a 143, a 154, a 160, a 165, a 173, or a 182, and wants either or all of them, has but to ask to receive. Nos. 93, 99, 108, 116, 123, 130 and 135 are out of print. Circular No. 1—free for the asking—outlines all these bulletins except the last four issued. Circular 7 on "Plant Food Combinations for Sundry Crops" contains a reprint of the more important formulas, etc., originally issued in bulletin 116.

THE FERTILIZER LAW (CHAPTER 213 P. S.)

The term "commercial fertilizer" is defined to mean "compounds and manufactured substances containing * * * two or more of the ingredients" (nitrogen, potash, phosphoric acid) but not "the separate ingredients used to manufacture the same, or * * * bone meal, land plaster, lime or a substance the product of nature which is not compounded." (Sec. 4973 P. S.).

The law provides that "every lot * * * of commercial fertilizer * * * shall be accompanied by a * * * statement * * * certifying the number of net pounds, * * * the * * * brand, * * * the name and address

of the manufacturer, * * * and a chemical analysis stating the minimum percentages of nitrogen, of potash soluble in water, and of available and total phosphoric acids." (Sec. 4976 P. S. as amended by No. 182 of the Acts of 1912).

It provides that the "manufacturer, importer, agent or seller" (the latter only in case the manufacturer fails to comply with the law) " * * * shall annually * * * pay * * * a license fee of twenty dollars," which will permit "the sale of one brand of commercial fertilizer which shall be the product of the licensee." It further provides that "if a manufacturer * * * desires to sell * * * more than one brand, he shall annually * * * pay a license fee of twenty dollars for each * * * brand * * * in excess of one." "The fee (s) * * * cover and authorize sales * * * for the calendar year." (Secs. 4977-4978 P. S. as amended by No. 169 of the Acts of 1910).

It provides that any person offering unguaranteed, over-guaranteed or unlicensed goods shall be subject to a fine (Sec. 4981 P. S.); forbids the use of "leather or its products, hair, wool-waste, garbage tankage or inert nitrogenous material" unless explicit notice thereof be made (Sec. 4980 P. S.); provides that license fees be sent to the state treasurer, and for the reimbursement of the Experiment station for expenses incurred (Sec. 4982 P. S.); for sampling, analyses and publication (Secs. 4990 and 4991 P. S.); forbids interference (Sec. 4993 P. S.); and prescribes the procedure in case of violation (Sec. 4989 P. S.). The act does "not apply to persons manufacturing, importing or purchasing * * * fertilizers * * * for their own use and not for sale in this State." (Sec. 4992 P. S.).

The full text of the law will be furnished on application.

LIST OF LICENSEES

The following nineteen companies (or individuals) have paid licenses as required by law on the brands shown in the statements on pages 420-426 and in the tables on pages 428-439. The sale within state limits of these brands and of these brands only is legal. All local agents, as well as intending purchasers, are warned against the handling of other brands, unless bought for personal use and not for sale. They are likewise warned against the sale of mixed goods of companies other than those listed herewith, since they render themselves liable to pay the twenty dollar license fee. "Parties manufacturing, importing or purchasing fertilizers for their own use and not for sale in this State" are not affected by the restrictions of the law.

American Agricultural Chemical Co., 2 Rector St., New York, N. Y.
Armour Fertilizer Works, 930-938 Equitable Building, Baltimore, Md.
Bowker Fertilizer Co., 43 Chatham St., Boston, Mass.
J. F. Bromley, Granville, N. Y.
Burlington Rendering Co., North Ave., Burlington, Vt.
Coe-Mortimer Co., 51 Chambers St., New York, N. Y.
Essex Fertilizer Co., 39 North Market St., Boston, Mass.
International Agricultural Corporation, Buffalo Fertilizer Works, 812
Marine Bank Building, Buffalo, N. Y.
Listers' Agricultural Chemical Works, Lister Ave., Newark, N. J.
Lowell Fertilizer Co., 40 North Market St., Boston, Mass.
National Fertilizer Co., 92 State St., Boston, Mass.
New England Fertilizer Co., 40A North Market St., Boston, Mass.
Parmenter & Polsey Fertilizer Co., 41 North Market St., Boston, Mass.
Reading Bone Fertilizer Co., 32-34 North Sixth St., Reading, Penn.
Rogers and Hubbard Co., Middletown, Conn.
F. S. Royster Guano Co., 1604-1614 Munsey Building, Baltimore, Md.
J. W. Sanborn, Pittsfield, N. H.
Sanderson Fertilizer and Chemical Co., Box 172, New Haven, Conn.
Virginia-Carolina Chemical Co., 24 Broad St., New York, N. Y.

COLLECTION OF SAMPLES

The sampling agents of the Station visited 102 towns and villages in Vermont during the spring of 1915 and drew 656 samples from dealers' stocks, representing 173 distinct brands, the output of 19 companies or individuals licensed to sell in Vermont. A sample was secured of every brand which was licensed, except the following:

Armour's Five-Eight-Three,
Listers' Ammoniated Dissolved Superphosphate,
Listers' High Grade Special for Spring Crops,
Listers' Standard Pure Superphosphate of Lime,
National Fertilizer Co.'s Tobacco Special with Carbonate of Potash
(revised),
National Fertilizer Co.'s Universal Fertilizer.

SCHEDULE OF TRADE VALUES

The following schedule of trade values to be used in Vermont in 1915 is the one agreed upon by the Experiment stations of New England, New York and New Jersey, after a careful study of prices

ruling in the larger markets. The 1914 schedule is also shown for the purpose of comparison.

TRADE VALUES OF FERTILIZING INGREDIENTS IN RAW MATERIALS AND CHEMICALS
FOR 1914 AND 1915

	1914 cts. per lb.	1915 cts. per lb.
Nitrogen in nitrates	16½	15
Nitrogen in ammonia salts	16½	15½
Organic nitrogen in dry and fine ground fish, blood and meat	22½	22
“ “ in cottonseed meal and castor pomace..	22½	20
“ “ in fine ground bone and tankage.....	19½	21
“ “ in coarse bone and tankage	17½	17
“ “ in mixed fertilizers	19½	19
Phosphoric acid soluble in water	4½	4
“ “ soluble in ammonium citrate¹.....	4	3½
“ “ in fine ground bone and tankage.....	4	4
“ “ in cottonseed meal and castor pomace....	4	3½
“ “ in coarse bone and tankage.....	3½	3½
“ “ insoluble (in water and in ammonium citrate¹) in mixed fertilizers.....	2	2
Potash as high grade sulphate and in mixtures free from muriate (chlorid)	5	9½
Potash as muriate	4	8½
Potash in cottonseed meal and castor pomace.....	5	9½

¹Dissolved from 2 grams of the prepared sample, previously extracted with pure water, by 100 c. c. of a neutral solution of ammonium citrate, sp. gr. 1.09, in 30 minutes at 65 degrees C., with agitation once in 5 minutes.

These trade values, as nearly as can be estimated, are the average figures at which, in the six months preceding March 1st, the respective ingredients could be bought at retail for cash in the larger markets (Boston, New York, etc.), in the *raw materials*, unmixed. They also correspond to the average wholesale prices for six months ending March 1st, plus about 20 percent in the case of goods for which there are wholesale quotations. The valuations obtained by the use of the above figures will be found to agree fairly with the reasonable average retail price in the larger markets.¹

In applying trade values to mixed goods, organic nitrogen is valued at 19 cents a pound; nitrogen as nitrate of soda and as sulphate of ammonia at 15 and 15½ cents a pound respectively; soluble, reverted and insoluble phosphoric acids at 4, 3½ and 2 cents a pound respectively; and potash at 8½ cents a pound, if there is sufficient chlorin to unite with all the potash; if not, it is valued at 9½ cents.

A “valuation” is determined as follows: The percentages or pounds per hundred of each ingredient (i. e., nitrate nitrogen, ammonical nitrogen, organic nitrogen, soluble phosphoric acid, reverted phos-

¹These general statements are less applicable this year than usual owing to the untoward potash situation,

phoric acid, insoluble phosphoric acid and potash), are multiplied by 20, giving the number of pounds of each ingredient in a ton. These figures are multiplied then by their respective pound prices.

THE MEANING OF COMMERCIAL VALUATIONS

That there may be no misconception and that the reader may appreciate clearly what these valuations are and what they are not, it is our custom to call attention repeatedly to the fact that *a station valuation does not represent the proper selling price of a fertilizer at the point of consumption*. Neither should it be inferred that the ingredients in the brand in question have of necessity the commercial value indicated. It may be greater or less than is shown. The Station does not pretend dogmatically to state what may be the commercial worth or valuation of any one of the many brands of fertilizer which are sold today in the Vermont markets. The valuation system is based on the assumption that all brands are composed solely of high grade ingredients, an assumption which probably is erroneous. "Valuations" should not be construed as showing the commercial worth of a given fertilizer, but the *retail trade value or cash-cost of amounts of nitrogen, phosphoric acid and potash, equal to those contained in a ton of the brand in question, in unmixed, standard raw materials of good quality, at the seaboard*. They bear no necessary relationship to the agricultural or the crop producing value of the goods, but simply indicate the current market prices of standard commercial articles, more particularly nitrate of soda, sulphate of ammonia, tankage, ground bone, acid phosphate, muriate and sulphate of potash.

Valuations thus construed, while not infallible, are helpful:

(a) As a means of indicating whether a given fertilizer is worth its cost from the *commercial* standpoint.

(b) As a common basis on which to compare the *commercial* values of different brands, enabling buyers to note whether prices asked are warranted by values contained.

Valuations, then, simply show the cost of ready-made plant food. Its cost, however, is but one of the many charges which determine the retail price of commercial fertilizers, just as the leather of which a pair of shoes is made is but one of the many charges which go to make up the retail cost thereof. The various forms of plant food must be stored, commingled together and again stored, reground, bagged, loaded, and freighted. Then, too, commissions to agents and dealers, the expense of selling on long credit, the item of bad debts, the interest on investments, the depreciation of the manufacturing plant, profits,

etc., are also proper and fixed charges; yet not one of these so-called "overhead charges" contributes to plant growth.

An illustration may serve to make these statements more clear. A farmer buys in Boston or New York 100 pounds of nitrate of soda, 500 pounds of tankage, 1,300 pounds of acid phosphate, and 100 pounds of muriate of potash, and he mixes these ingredients together at home on his barn floor, as thousands have done before him. The cost of this ton after mixing will be made up as follows: (a) Cost of material in the market; (b) cost of transportation; (c) cost of mixing. The first item (a) entering into the total cost is the only one included in the "valuation." If to (a) be added (b), (c), and, also, the expenses of selling through agents, long credits, bad debts, etc., we have the factors involved in the sale of fertilizers delivered in Vermont. Clearly the local selling price must of necessity exceed the "valuation," since the cost of mixing and selling varies with different companies, and since freight rates to the different sections of the State are unlike, no arbitrary sum to cover these charges can be assigned. These can be estimated best by the consumer to fit his local conditions. He should expect to pay and does pay not only for the plant food contents of his purchase, but also a fair margin to cover the expenses incident to assemblage, manufacture and sale, as well as for the convenience and other advantages pertaining to the use of ready-made and locally supplied plant food as set forth somewhat fully on page 419 of this bulletin. If the selling price does not exceed the valuation by more than 35 or 40 percent it may not be too high, but in proportion as the excess increases beyond this point there is reason to question the economy of the purchase. The reader is referred for a further and somewhat full discussion of this matter to pages 340-345 of bulletin 160, also the special article in bulletin 143, pages 183-192, dealing with the exposition of the meaning of the analyses and valuations.

III. RESULTS OF FERTILIZER INSPECTION

1. AS TO THE QUANTITY OF PLANT FOOD

(a) COMPARISON OF GUARANTIES AND ANALYSES

The general quality of the fertilizers sold in Vermont in 1915 is good, so far as comparison with guaranty is concerned. The number of shortages is the normal one and the proportion of brands which are up to or better than guaranty is as usual. The shortages are almost all little ones, minor sins. In only 7 cases are failures to make good manufacturers' promises worth stressing and in only 2 cases need any fuss be made. In other words five-sixths of the brands sold this year are as good as they were said to be and only two or three failed to afford the commercial equivalent of the manufacturers' promises, and these by comparatively small amounts, the largest being well under a dollar.

A few brands lacked in two ingredients, or, indeed, in all three. No manufacturer has thus far, fully six weeks after submitting the analytical results, questioned their accuracy. The writers believe that the analyses correctly represent the samples submitted by the sampling agents. Furthermore, either through resampling or through careful scrutiny of the local situation, they have become satisfied that the samples were truly representative of the shipments made to the points at which the samples were drawn. In one or two cases the analyses were made so late in the season that it was impracticable to resample.

The general situation is a good one. Faulty fertilizers, as judged by the comparison of promise and performance, are not very common, and the trade seems to be in a healthy condition. Indeed, comparison with the results attained in other states is on the whole a favorable one, since the proportion of guaranty maintenance seems better in Vermont than that commonly found elsewhere. Commercial fertilizers are shipped into this State earlier than into most of the other northern states. Whether to this fact or to other causes may be attributed the relatively small proportion of failures to furnish the promised plant food which usually obtains in Vermont cannot be said; but certain it is that, as judged by several years' control work, the Vermont farmer rarely buys a fertilizer of lower grade than is promised him.

The plant food shortages in the 29 deficiencies were distributed as follows: Nitrogen, 7; available phosphoric acid, 16; potash, 10. Only seven of the 508 guaranties made on 173 brands by 19 manufacturers,

or one in 73, were not made good within 0.50 percent of a single ingredient; and only two were lacking to an extent greater than 0.75 percent; an excellent result.

The condensed results of 20 years' inspection of the Vermont trade, so far as they relate to the maintenance of guaranty, follow:

Year	Number of brands analyzed	Number of brands up to or above guaranty through-out	Number of brands deficient	Percent of total number up to or above guaranty	Percent of total number at-fording commercial equivalent of guaranty
1896	110	91	19	83	99
1897	134	113	21	84	94
1898	126	113	13	90	100
1899	137	105	32	77	90
1900	132	114	18	86	96
1901	134	118	16	87	99
1902	136	123	13	90	100
1903	111	106	5	96	100
1904	118	94	24	80	97
1905	130	92	38	71	94
1906	130	110	20	85	98
1907	129	99	30	77	94
1908	130	92	38	71	95
1909	133	111	22	83	96
1910	152	138	14	91	100
1911	157	146	11	93	99
1912	182	156	26	86	98
1913	177	153	24	86	98
1914	185	153	32	83	97
1915	173	144	29	83	98

Whenever guaranties were not made good the analytical work was repeated, and invariably recourse was had to other samples taken a second time from the original shipments, except in cases where the goods had been used prior to the attempt a second time to sample them. When results seemed open to question, other samples elsewhere drawn were analyzed. Unusually high figures were similarly checked. Careful comparisons with the analytical results of previous years were instituted with a view of minimizing error and standardizing results.

The following table shows the number of brands sold by the different companies licensed in Vermont, the number of guaranties (nitrogen, available phosphoric acid, potash) made by each, and the number of failures to make the same good within the tolerance figures long adopted at this Station, namely, 0.10 percent of nitrogen and 0.20 percent of available phosphoric acid or potash.

MAINTENANCE OF GUARANTIES BY LICENSEES

Name of company	Number of brands	Number of guaranties	Number of guaranties not made good	Number of brands not making good the commercial equivalent of the guaranty
American Agricultural Chemical Co.	9	25	3	0
Bradley Fertilizer Co. branch	12	35	0	0
Cleveland Dryer Co. branch	3	9	0	0
Crocker Fert. and Chem. Co. branch.....	4	12	0	0
L. B. Darling Co. branch	3	9	0	0
Great Eastern Fertilizer Co. branch.....	4	12	0	0
Pacific Guano Co. branch	3	9	0	0
Quinnipiac Co. branch	3	9	0	0
Read Fertilizer Co. branch	4	11	0	0
Williams & Clark Fertilizer Co. branch...	7	21	0	0
American Agricultural Chemical Co.—Total	52	152	3	0
Armour Fertilizer Works	7	20	8	2
Bowker Fertilizer Co.	13	39	2	0
J. F. Bromley	4	11	1	0
Burlington Rendering Co.	4	12	0	0
Coe-Mortimer Co.	11	32	0	0
Essex Fertilizer Co.	6	18	0	0
International Agricultural Corporation, Buffalo Fertilizer Works	9	26	5	1
Listers' Agricultural Chemical Works	6	17	0	0
Lowell Fertilizer Co.	10	30	1	0
National Fertilizer Co.	5	15	1	0
New England Fertilizer Co.	7	21	1	0
Parmenter and Polsey Fertilizer Co.	3	9	0	0
Reading Bone Fertilizer Co.	9	26	3	0
Rogers and Hubbard Co.	8	24	5	1
F. S. Royster Guano Co.	5	15	1	0
J. W. Sanborn	3	9	0	0
Sanderson Fertilizer and Chemical Co.	4	12	0	0
Virginia-Carolina Chemical Co.	7	20	2	0
Total	173	508	33	4

Twelve of the 19 companies contribute brands to the delinquent list. Five furnish a single brand each; two, 2; two, 3; one, 4; and two, 5 brands.

The range of composition and the closeness with which guaranties are met are displayed in the following table. The condition of affairs it discloses, a close hugging of the guaranties, has obtained for years, as appears in the second table, which shows the excess of the average analysis over the average guaranty for five years. The manufacturers naturally do not mean to place more plant food than is absolutely necessary in their goods, which carry on the average rather less than ten percent excess over the minimum guaranty. Maximum guaranties, of course, are quite meaningless.

MAINTENANCE OF GUARANTIES BY LICENSEES

	PERCENT GUARANTIED			PERCENT FOUND			Excess of average analysis over guaranty
	Lowest	Highest	Average	Lowest	Highest	Average	
Nitrogen	0.8	*8.5	†2.34	0.56	8.55	†2.65	0.31
Total phosphoric acid	4.	16.	9.21	4.56	17.11	10.09	0.89
Available phosphoric acid....	3.	14.	8.13	3.47	15.35	8.66	0.53
Potash	1.	4.	2.86	0.86	4.79	3.00	0.14
Selling price	\$21.00	\$58.00	\$33.06				
Valuation	\$10.60	\$37.65	\$19.28	\$10.70	\$38.89	\$20.64	\$1.36

*Nitrogen in 11 brands.

†Non-nitrogenous goods omitted; if included, average drops 0.14 percent in guaranties and 0.17 percent in actualities.

FIVE YEARS' COMPARISON OF THE EXCESS OF ANALYSES OVER GUARANTIES

	1911	1912	1913	1914	1915	Average for 5 years
Nitrogen	0.20	0.21	0.20	0.17	0.31	0.22
Total phosphoric acid	1.16	1.02	0.82	0.85	0.89	0.94
Available phosphoric acid	0.73	0.29	0.41	0.44	0.53	0.48
Potash	0.26	0.47	0.54	0.29	0.14	0.34
Valuation	\$1.82	\$1.20	\$1.90	\$1.35	\$1.36	\$1.53

While the above statement shows that the goods compare well on the average with the claims made for them, the tables on pages 428-439, as well as the statements on pages 406-408, betray the fact that within this average lie concealed a few small deficiencies. It is but scant satisfaction to the buyer of a brand in which the amount of plant food guaranteed is not furnished to know that the "average" is good. It is for him to exercise care and avoid buying such goods. Yet it should be said that this year no *seriously* faulty fertilizers, so far as guaranty maintenance is concerned, were sold. Some years, however, very deficient goods have been offered.

(b) COMPARATIVE VALUES OF FERTILIZERS IN 1914 AND 1915

It has been customary at this point in the annual fertilizer bulletin to compare averages. Thus last year at this point it was said that "of the 193 brands of commercial fertilizers which were sampled by the Station during 1913 and 1914, 169 have been selected for the purpose of instituting a comparison of the characters of the goods sold under these brand names in each of the two years. Only those brands have been chosen which have been sampled both years." No such sweeping

comparison can be made this year. Manufacturers have been forced by the potash situation markedly to modify many of their brands as to their guaranties. Many of the manufacturers have used new brand names or old ones slightly modified to meet this untoward situation. Others have sold their goods with unchanged brand names, but changed guaranties. It should be distinctly understood that this latter procedure is no crime, since the law does not and cannot control as to names. A manufacturer may, if he wishes, sell a high grade product in 1914 named, let us say, Smith's Mighty Melon Maker, and in 1915, using precisely the same brand name, sell the lowest of the low grades. Caveat emptor; it is for the buyer to beware, to watch guaranties and to buy accordingly.

The following statement shows this year's practice of Vermont licensees as to brand names.

The following named companies substituted new lists of brands, the names being quite unlike those of the brands previously sold.

Armour Fertilizer Works, F. S. Royster Guano Co.

The following named companies sold some brands the names and guaranties of which were unchanged; offered others the names of which were more or less modified and guaranties altered; and introduced a few new brands.

American Agricultural Chemical Co., Bowker Fertilizer Co., Coe Mortimer Co., Listers' Agricultural Chemical Works, National Fertilizer Co., New England Fertilizer Company, Sanderson Fertilizer and Chemical Company.

The following party did not license his high potash brand in 1915 and sold only the brands he had hitherto sold carrying low potash content.

J. B. Bromley.

The following companies sold goods of lowered guaranties under the identical brand names used in previous years.

Burlington Rendering Co., Essex Fertilizer Co., International Agricultural Corporation Buffalo Fertilizer Works¹, Lowell Fertilizer Company,² Parmenter and Polsey Fertilizer Co., Reading Bone Fertilizer Company, Rogers and Hubbard Co., J. W. Sanborn.

(c) COMPARATIVE VALUE OF FERTILIZERS FROM 1896 TO 1915

The next table shows the average composition of the fertilizers as analyzed during the last 20 years. Every brand tested each year is included in the comparison, each one being given equal value. It

¹A few new brands were also sold.

²Several brands unchanged as to guaranties.

is well understood that this is not strictly a correct method of calculation, but it is the best which can be done in the absence of data showing the consumption of individual brands. Inasmuch as high grade goods in the past have sold slowly, and, unfortunately, low grade

AVERAGE COMPOSITION OF FERTILIZERS SOLD IN VERMONT FROM 1896 TO 1915¹

Year	Number of brands	Nitrogen	PHOSPHORIC ACID					Potash
			Soluble	Reverted	Insoluble	Total	Available	
1896	110	2.22	5.36	3.44	2.23	11.03	8.80	3.66
1897	134	2.12	5.34	3.68	2.23	11.25	9.02	3.43
1898	126	2.21	5.51	3.32	2.08	10.91	8.83	3.81
1899	137	2.06	5.08	3.32	2.26	10.66	8.40	4.10
1900	132	2.08	5.29	3.26	2.58	11.13	8.55	3.80
1901	134	2.08	5.34	3.23	2.41	10.98	8.57	4.33
1902	136	2.22	5.56	3.06	2.39	11.01	8.62	4.21
1903	111	2.02	5.13	3.42	2.50	11.05	8.55	3.79
1904	118	1.98	5.20	3.19	2.38	10.77	8.39	3.95
1905	130	2.03	4.63	3.63	2.63	10.89	8.26	4.18
1906	130	2.09	4.70	3.65	2.63	10.98	8.35	4.37
1907	129	2.16	4.40	3.60	2.40	10.40	8.00	4.65
1908	130	2.05	4.64	3.50	2.29	10.43	8.14	4.58
1909	133	2.08	5.25	3.07	2.21	10.53	8.32	4.70
1910	152	2.12	5.50	2.86	1.53	9.89	8.36	4.99
1911	157	2.06	5.69	2.60	1.56	9.85	8.29	4.94
1912	182	2.19	4.99	2.92	1.75	9.66	7.91	5.55
1913	177	2.37	4.69	3.16	1.37	9.21	7.84	5.96
1914	185	2.32	4.68	3.19	1.51	9.38	7.87	5.77
1915	173	2.48	4.81	3.85	1.43	10.09	8.66	3.00

AVERAGE COST OF FERTILIZERS SOLD IN VERMONT FROM 1896 TO 1915

Year	Number of brands	Average ton selling price	Valuation each year's trade values	Selling price exceeds valuation	Selling price exceeds valuation, percent	Value of plant food rec'd for a dollar	Valuation at 1915 trade values
1896	110	\$30.90	\$19.73	\$11.17	57	64 cts.	\$21.36
1897	134	29.19	19.47	9.72	50	67 cts.	20.78
1898	126	29.04	17.86	11.18	63	61 cts.	21.56
1899	137	28.75	17.39	11.36	65	60 cts.	21.26
1900	132	28.73	18.08	10.65	59	63 cts.	21.07
1901	134	28.75	19.44	9.31	48	68 cts.	21.92
1902	136	28.23	20.18	8.05	40	71 cts.	22.26
1903	111	28.25	18.59	9.66	52	66 cts.	20.80
1904	118	29.00	18.47	10.53	57	64 cts.	20.80
1905	130	29.62	19.04	10.58	56	64 cts.	21.30
1906	130	29.52	19.38	10.14	52	66 cts.	21.91
1907	129	30.57	21.21	9.36	45	69 cts.	22.25
1908	130	31.24	20.75	10.49	51	66 cts.	21.84
1909	133	31.43	18.84	12.59	67	60 cts.	22.29
1910	152	31.45	20.57	10.88	53	65 cts.	22.70
1911	157	31.41	19.53	11.88	61	62 cts.	22.39
1912	182	32.03	20.09	11.94	59	63 cts.	23.62
1913	177	32.64	21.24	11.40	54	65 cts.	24.70
1914	185	32.53	20.35	12.18	60	63 cts.	24.28
1915	173	33.06	20.64	12.42	60	59 cts.	20.64

¹ See accompanying statements as to average.

brands as a rule readily, the actual average as used is probably somewhat lower than that shown in the table. Yet the evidence in hand indicates a rapidly lessening usage of low grades and a larger usage of medium and high grades.

It ought to be remarked at this point that neither this table, nor the discussion of the table, should be construed too literally, for the reasons cited as to the usage of the several brands. Some attempt was made a dozen or more years ago to estimate the relative usage of the different grades, but without much success. No data are available that are trustworthy, while if one appeals to the individual judgment of those who are in close touch with the trade, the inevitable personal equation enters to a large extent. The result of such an inquiry therefore seems so largely a matter of guesswork as to be hardly worth recording. The writer's judgment would place the average goods as actually used of late years at approximately 2.1 percent nitrogen, 8.5 percent available phosphoric acid, and 3.7 to 4 percent potash and of this year's, 2.3 percent nitrogen, 8.7 percent available phosphoric acid, and 2.5 percent potash. The relatively large usage of the medium grades and the less frequent usage of the higher grades which doubtless obtains tend to lower the general average.

The average commercial fertilizer sold in Vermont in 1914 contains 0.25 percent more nitrogen, 0.50 percent less available phosphoric acid and a percent more potash than the average sold in the decade previous to 1912 and this year's average compared with last year's is 0.2 percent higher in nitrogen, 0.8 percent higher in available phosphoric acid and 2.75 percent lower in potash.

The increase in the average of the ten years, 1905-1914, as compared with those of previous years is due to the high grade of certain goods sold for the first time in 1905, and to the entry in each of several years since, and especially during 1912-1914, of a number of very high grade goods. There are 50 more brands sold in Vermont today than were offered 5 years ago. This change in average quality is doubtless more apparent than real, for the newcomers inevitably are not at the outset as widely sold as are the old-timers. A survey of the table on the preceding page indicates that there has been on the whole an up-grading in the last 20 years in the character of the goods used by Vermont farmers. Indeed there seem to be four periods of 4, 6, 7 and 3 years respectively, wherein there are to be found somewhat wide variations in the plant food contents of the average goods, particularly in phosphoric acid and potash as is shown in the following table:

1895-98.....	nitrogen 2.19, available phosphoric acid 8.75, potash 3.60
1899-04.....	nitrogen 2.07, available phosphoric acid 8.51, potash 4.06
1905-11.....	nitrogen 2.08, available phosphoric acid 8.25, potash 4.63
1912-14.....	nitrogen 2.29, available phosphoric acid 7.87, potash 5.76
1915.....	nitrogen 2.48, available phosphoric acid 8.66, potash 3.00

It is generally understood that the fertilizer trade has been seriously handicapped owing to conditions arising from the war. The only commercial supply of potash is obtained from Germany. The strict embargo has shut off the supply. A sufficiency was on hand to enable the trade to place not to exceed 4 percent in the 1915 goods. In a general way in lowering the potash contents, the nitrogen contents have been slightly and the available phosphoric acid contents somewhat augmented; but these increments have not equalled the shortages, particularly in the high grade brands. The average low grade fertilizers sold in Vermont this year carried a percent less potash and a half percent more available phosphoric acid than that sold in 1914, a shortage of 5 percent in plant food; the average medium grade carried 2.5 percent less potash, but a quarter percent more nitrogen and three-fourths percent more available phosphoric acid than the same grade sold last year, a shortage of 10 percent in plant food; and the average high grade brands contained nearly 5 percent less potash and a quarter percent more nitrogen and nearly one and a quarter percent more available phosphoric acid than did the 1915 high grades, a shortage of 17 percent.

It should be clearly understood that the fertilizer trade is not to blame for these shortages. Its goods are manufactured in the summer and fall. The situation with which it was suddenly confronted last fall and winter could neither have been foreseen nor forestalled. Paraphrasing the famous aphorism of former days, farmers may cry potash, potash, but there is no potash; nor does it seem likely that there will be any, commercially speaking, until the blockade is lifted.

At what prices did the various forms of available plant food sell in the average mixed fertilizer during all these years? These data are afforded by the following table, from which it is evident that the tendency of late years has been towards increased selling prices. This is particularly true of the medium and high grade goods.

COST OF PLANT FOOD IN THE AVERAGE MIXED FERTILIZER, 1896 TO 1915

	Number of brands analyzed	Cost of one pound of organic nitrogen	Cost of one pound of available phos- phoric acid	Cost of one pound of potash (as muri- ate)
1896.....	110	22.0 cts.	8.6 cts.	7.1 cts.
1897.....	134	21.0 "	8.3 "	6.8 "
1898.....	126	22.8 "	7.3 "	6.9 "
1899.....	137	23.1 "	7.4 "	7.0 "
1900.....	132	24.6 "	7.1 "	6.7 "
1901.....	134	23.7 "	7.4 "	6.3 "
1902.....	136	23.1 "	7.0 "	6.0 "
1903.....	111	25.9 "	6.8 "	6.5 "
1904.....	118	27.5 "	6.9 "	6.7 "
1905.....	130	28.9 "	6.8 "	6.6 "
1906.....	130	28.3 "	6.6 "	6.4 "
1907.....	129	29.6 "	6.9 "	6.1 "
1908.....	130	30.6 "	7.1 "	6.3 "
1909.....	133	31.7 "	6.3 "	7.1 "
1910.....	152	30.6 "	6.6 "	6.5 "
1911.....	157	32.2 "	7.0 "	6.8 "
1912.....	182	30.2 "	6.9 "	6.8 "
1913.....	177	29.2 "	6.7 "	6.5 "
1914.....	185	31.2 "	6.9 "	6.4 "
1915.....	173	30.4 "	6.1 "	13.6 "

2. AS TO QUALITY OF PLANT FOOD

(a) SOURCES OF PLANT FOOD IN LICENSED FERTILIZERS

The table on page 400 as well as those on pages 428-439 show wide ranges in composition, amounts of nitrogen varying from 0.56 to 8.55 percent, of available phosphoric acid from 3.47 to 15.35 percent, and of potash from 0.86 to 4.79 percent. These figures alone, however, do not tell the whole story or, indeed, much of the story, as to the character of the ingredients used, a matter of quite as much importance as their amounts. A further scrutiny into the details of the sundry analyses throws some light on the sources whence the plant food purveyed in the various brands is derived.

NITROGEN

In all but 19 of the 162 nitrogenous brands, nitrate or ammoniacal nitrogen were found present in appreciable amounts and in half of these few some little ammoniacal nitrogen seems present. Some of the 19 manufacturers selling in Vermont have for many years used nitrate of soda or sulphate of ammonia as a means of supplying nitrogen;

others have resorted to the use of mineral forms of nitrogen only within the past few years. Doubtless the fact that mineral nitrogen is much cheaper today than is organic nitrogen explains its present freer usage. Time was, not long ago, when the ratio of mineral to organic nitrogen was much less than it is today in the goods sold in Vermont, and when a large share of the goods contained neither nitrate nor ammonia salts. The amounts found in this year's goods vary from 0.07 to 8.17 percent, averaging 1.49 percent or 60 percent of the total nitrogen present in the brands carrying this ingredient, a very different situation than formerly obtained. Under certain circumstances and for certain purposes mineral nitrogen, particularly in the nitrate form, is to be preferred agriculturally to organic nitrogen; under other circumstances it is not as much to be desired. It is more readily available but is more easily lost by leaching. Speaking broadly, however, the presence of mineral nitrogen in commercial fertilizers is to be favored for most of the purposes for which such goods are used in Vermont. It is an open question, however, whether manufacturers are not going too far in this matter. Sixty percent of nitrogen in mineral forms in some seasons may be a somewhat larger proportion than can be used to good advantage. An over-supply may be present at the outset and, following heavy rains, an under-supply during late July and August; yet on the other hand it is but fair to admit that manufacturers are often at their wit's end in attempting to secure an adequate supply of organic nitrogen of good grade. The fertilizer tonnage is increasing by leaps and bounds. In 1900 there were produced in the United States 2,200,000 tons; in 1913, more than 6,800,000 tons; and the increased crop acreage of 1915 doubtless is absorbing fully 7,500,000 tons. Yet in the face of this situation the supply of many forms of organic nitrogen is shrinking both relatively and actually. Just what will happen a decade hence is not easy to foretell.

All the brands which carry nitrogen contain more or less organic nitrogen, derived doubtless as a rule from standard animal and vegetable ammoniates, such as dried blood, meat meal, fish scrap, tankage, etc. Probably tankage is at present its main source in a large proportion of the brands.

AVAILABILITY OF ORGANIC NITROGEN

For the fifth time this Station, joining with its sister stations in the North Atlantic states, prints in its table of analyses tabulated data as to the character of the organic nitrogen used in the various brands offered for sale, with a view of indicating its serviceability

to crop growth. This Station for nearly 20 years has thus "kept tab" on the several brands offered for sale. It has formed an opinion in many cases of the character of the organic nitrogen used therein. It has not hesitated by correspondence and by personal interview to question the character of the organic nitrogen used in certain brands, and in times past has not infrequently found its queries to be justified by facts, either directly acknowledged, or at least not gainsaid, by the manufacturers. Its long experience with the alkaline permanganate method of determining organic nitrogen availability, the long series of analytical results accumulated in its files during the past 18 years, the work done by other stations in this section of the country using the same method, have served to give it confidence in the essential accuracy of its findings. But it has not deemed itself justified prior to 1911 in publishing the results as applied to the separate brands of goods as found on sale.

The nitrogen contents of a fertilizer are now stated in the analytical tables in the following terms: Nitrogen in nitrates; nitrogen in ammonia salts; water soluble organic nitrogen; active water insoluble organic nitrogen; inactive water insoluble organic nitrogen; total nitrogen found.

1. *Nitrogen in nitrates.* The percentage of nitrogen derived from nitrate of soda, a soluble mineral form of nitrogen immediately available to plant growth.

2. *Nitrogen in ammonia salts.* The percentage of nitrogen derived from sulphate of ammonia, a high grade gas-house or coke-oven by-product¹; a mineral form of nitrogen readily available to plant growth.

3. *Water soluble organic nitrogen.* The percentage of nitrogen derived from organic sources which is soluble in water.¹ The presumption is that most organic nitrogen soluble in water is likely on that account to be relatively available to plant growth.

4. *Active water insoluble organic nitrogen.* The percentage of such organic nitrogen as is not soluble in water, but notwithstanding, is deemed to be relatively available to plant growth, this judgment being based upon the relative readiness with which it has been acted upon by the chemicals used in the modified alkaline permanaganate method as well as upon extensive vegetation trials.

5. *Inactive water insoluble organic nitrogen.* The percentage of the water insoluble organic nitrogen that has not been acted upon by

¹The nitrogen derived from calcium cyanamid would appear either here or as "water soluble organic nitrogen," or both, according to circumstances.

the chemicals used in the modified alkaline permanganate process. It is held to be considerably less available to plant growth than are those forms which are scheduled under the other heads.

As a rule brands which carry more inactive water insoluble nitrogen than active water insoluble nitrogen should be looked at askance; and this is particularly true if the water soluble organic nitrogen contents are relatively small.

As a rule the organic nitrogen availabilities of the several brands sold in Vermont during 1915 are above reproach. Attention should be called, however, to the character of the organic nitrogen used in the following brands, a large proportion—indeed in some cases a very large proportion—of which is deemed to be agriculturally inferior in quality.

J. B. Bromley.....	Special Corn Fertilizer
International Agricultural Corporation, Buffalo Fertilizer Works	Farmers' Choice (E 1) New England Special (E 2) One-Eight-Two
Sanderson Fertilizer and Chemical Company	Atlantic Coast Bone, Fish and Potash Potato Manure
Virginia-Carolina Chemical Co.	Ammoniated Potash Compound Universal Potash Phosphate XXX Fish and Potash

It should be said in this connection that some shipments of the Farmers' Choice (R 3) and New England Special brands manufactured by the International Agricultural Corporation, Buffalo Fertilizer Works, were found above reproach in respect to their organic nitrogen contents.

PHOSPHORIC ACID

Some companies furnish more total phosphoric acid in available form than do others; some, more of the water soluble relative to the citrate soluble or reverted than do others. Water soluble phosphoric acid cannot be other than of the best grade and is to be preferred to that not thus soluble. Citrate soluble phosphoric acid, while often, and perhaps usually, quite as good agriculturally as that which is soluble in water, may be of distinctly lower grade (agriculturally) if certain classes of phosphatic crude stock, such, for example, as ignited alumina phosphate, are used. Low soluble and high reverted phosphoric acid contents do not of necessity mean that the available phosphoric acid is not as serviceable as when the conditions are reversed, but that the likelihood of this being true is lessened.

The proportions of the total phosphoric acid found in the various brands to be in available forms varied from 48 percent to 96 percent. The proportions of available phosphoric acid found to be in a water soluble form varied from zero to 89 percent. Grouped according to their manufacture it was found that extremes for available in total were 65 and 90 percents, for water soluble in available 19 and 76 percents. In other words the average goods made by one firm carried 90 percent of the total phosphoric acid in available form, while those made by another firm furnished but 65 percent in that shape, the remainder ranging between. Similarly, on the average 76 percent of the available phosphoric acid furnished by one manufacturer was soluble in water, while only 19 percent was thus soluble in the average goods of another firm. The low availability seems to be due in certain cases to the use of considerable quantities of incompletely dissolved bone or of bone meal. Whether in other cases it is due to this cause, to imperfectly cut phosphate rock, to the age of the goods, to the use of agriculturally inferior forms of phosphoric acid, or to other causes does not always appear.

POTASH

This ingredient is sold in mixed goods in the form of muriate, sulphate, kainit, or, very rarely, nitrate. For many years the direct or inferential claim was made for two-thirds or more of the brands selling in Vermont that sulphate of potash was used in their manufacture. It was made in 1912 for only a fourth, in 1913 for less than a tenth of the entire number and for but very few in 1914 and 1915. This is as it should be, for as a matter of fact only six of the 173 brands contained sulphate of potash whatsoever, and only two of these six any large proportion, as is shown in the tables on pages 428-439. Practically sulphate of potash does not enter into the Vermont fertilizer trade, for the few brands in which it is present apparently do not enjoy large sales. Wherever the asterisk (*) or dagger (†) appear in connection with the potash figures in the columns thus headed on pages 431, 433, 434, 436, 438 and 439, sulphate of potash was found to be present; where these signs do not appear, the potash was derived from muriate or kainit, or else a sufficiency of chlorin was present in other combinations to mask the presence of sulphate and entirely to nullify its good effects, if any such there be.

It is, of course, always possible, though highly improbable, that sulphate of potash is used in conjunction with chlorin-containing ingredients, such, for instance, as common salt or magnesium chlorid.

If so, the manufacturer's good faith should not be impugned, but his judgment would be open to question. The only valid reason now known for using the more costly sulphate of potash is in order to exclude chlorin. Injury to plant growth from chlorin, if such occur, would be wrought thereby whether this element were derived from muriate of potash or elsewhere. Hence in order to receive credit for the use of sulphate of potash, manufacturers must exclude all chlorin carriers.

The situation in the fertilizer trade brought about by the European war makes potash a luxury. No goods sold in Vermont this year carry more than 4 percent; and what next year's brands will carry, quien sabe? What shall we do for potash? This year's fertilizers carried but little potash, although nearly or quite as much as those sold in Vermont in the eighties and early nineties. Next year's goods are likely to contain little or none. What should farmers do? Efforts may be made to render available larger proportions of the potash naturally present in the soil. Liming to some extent frees soil potash from its insoluble combinations and under some circumstances may in part offset the deficiency of potash. Soils on which highly potassic fertilizers have been freely used in the past may not show the effects of marked deficiencies for a year or two. It is held by some authorities—but questioned by others—that when the supplies of available potash salts are scanty the use of sodium salts may increase crop yields. Thus common salt, the use of which at times has proven beneficial, seems to have tended to liberate potash from the soil. Crude sodium carbonate or soda ash, which at times may be bought at low prices, might serve not only to sweeten soils but to liberate soil potash.

IV. THE RELATION BETWEEN SELLING PRICE AND VALUATION

The relationship of the selling price to the valuation of fertilizers of different grades has been elaborated annually for nearly 20 years. It has been customary of late to approach the matter from two directions, to make two classifications, basing one on *cost* and the other on *value*. Three groups, somewhat arbitrarily formed, designated "low priced," "medium priced" and "high priced," furnish the means of comparing the cost, while as many groups, termed "low grade," "medium grade" and "high grade," serve the purposes in the study of relative values. When grouped according to selling prices the item of *cost* is emphasized; when the valuations govern the subdivisions, the

stress is laid upon the *worth* of the material. The selling price may or may not bear an essentially just relation to the plant food content of the fertilizer. The valuation, however, is a more exact measure. Since both cost and worth are important factors, and since some may grasp the facts readily when presented from one point of view while others see the situation better when looked at from the other side, it has been deemed best to present the results of both methods of comparison. The general outcome is much the same, either way the proposition is figured.

1. FROM THE STANDPOINT OF COST

The brands may be classified as to selling price as follows:

	Number of brands	Percent- age of total	Average selling price	Average valuation
Low priced, selling at \$29.50 or below	55	32	\$26.46	\$14.65
Medium priced, selling from \$30 to \$34	60	35	31.84	19.97
High priced, selling for \$34.50 or more	58	33	40.35	26.95

The average, largest and smallest values of plant food offered in the groups of brands appear below. The figures show the values of plant food bought for a dollar in the average goods of each grade, including the greatest as well as the least value obtained in any brand in each class.

VALUE OF PLANT FOOD BOUGHT FOR A DOLLAR

	Average	Smallest	Largest
Low priced	\$0.55	\$0.43	\$0.72
Medium priced	0.63	0.50	0.77
High priced	0.70	0.53	0.79

It is interesting to note the number of brands in each group which furnish less than 55 cents' worth of plant food for a dollar, as well as the number which afforded more than 65 cents' worth for the same sum:

Low priced:	Less than 55c. worth, 21; more than 65c. worth, 2
Medium priced:	Less than 55c. worth, 5; more than 65c. worth, 14
High priced:	Less than 55c. worth, 5; more than 65c. worth, 38

The comparisons can be shown graphically. The relative length of the following lines shows the average money value in plant food at retail seaboard prices bought for a dollar at Vermont delivery points in brands selling for \$29.50 or less, (low priced), from \$30 to \$34 (medium priced), and for \$34.50 and above (high priced):

Low priced: 55 cents for a dollar spent.

Medium priced: 63 cents for a dollar spent.

High priced: 70 cents for a dollar spent.

The following lines show the proportion of the total number of brands in each group containing 55 cents or less worth of plant food¹ for each dollar paid for the fertilizer:

Low priced: 38%.

Medium priced: 8%.

High priced: 2%.

The final set of lines shows the proportion of the total number of brands in each group containing 65 cents or more worth of plant food for each dollar paid for the fertilizer:

Low priced: 4%.

Medium priced: 23%.

High priced: 66%.

If lines and figures are put into words, it will be seen that:

1. The same amounts of plant food which cost a dollar in the average low priced brands (\$29.50 and below) might have been bought in the unmixed state at retail and at the seaboard for 55 cents; in the average medium priced goods (\$30 to \$34), for 63 cents; and in the average high priced goods (\$34.50 and upwards), for 70 cents. Extremes of values were 79 and 43 cents. In one-sixth of the brands the sums charged for manufacture, transportation, sale, etc., comprised more than 45 percent of the retail cost, thus leaving less than 55 percent to pay for the plant food; while in 12 brands these charges equalled or exceeded the seaboard value of unmixed plant food.

2. In more than a third of the total number of low priced brands the charges for mixing, sale, etc., aggregated at least 45 percent of the selling price, while in only one-twelfth of the number of medium priced brands were the charges thus large. But a single high priced brand is thus listed.

3. Two-thirds of the total number of high priced goods contained an equivalent of 65 cents' or more worth of plant food at retail seaboard prices. But one in 4 of the medium priced and but one in 28 low priced goods contained so high an equivalent.

¹The phrase "55 cents' worth of plant food" should be construed to mean an amount of plant food which, if bought for cash at retail at the seaboard, would have cost 55 cents in standard, unmixed, raw materials.

These things are naturally so, inevitably so. There are good and sufficient reasons for this showing, which may be condensed in a nutshell as follows: It costs as much to mix, to store, to regrind, to bag, to ship, to freight, to sell, to collect for sales, etc., a ton of goods carrying 1,200 pounds of genuine fertilizer and 800 pounds of mere filler (diluent) as it does to mix, store, regrind, bag, freight, sell, etc., etc., a ton of goods containing a full 2,000 pounds of undiluted fertilizing crude stock. Hence it follows that the buyer of low priced goods must pay for all this useless handling of the nearly or quite worthless filler. It is an old story, reiterated year after year, but it is one which needs to be told as long as material usage of low priced brands obtains.

THE COST OF FERTILIZERS IN 1915

What have fertilizers cost during this year of stress and strain as compared with last year, when conditions were normal?

The following table sets forth this situation:

	Average	Low grade	Medium grade	High grade
Selling price 1914.....	\$32.53	\$26.25	\$30.88	\$40.21
Selling price 1915.....	33.06	26.67	32.11	39.55
Increase or decrease.....	+0.53	+0.42	+1.23	-0.66
Valuation 1914	\$20.35	\$14.04	\$19.32	\$27.93
Valuation 1915	20.64	14.44	19.98	27.52
Increase or decrease.....	+0.29	+0.30	+0.66	-0.41
Selling price exceeded valuation:				
In 1914	\$12.18	\$12.21	\$11.56	\$12.28
In 1915	12.42	12.23	12.13	14.03

It appears:

1. That the average 1915 goods cost a half dollar more than did the average 1914 goods and that, as judged by the application of the trade values and subject to the limitations set forth on page 409 of this bulletin, they were worth a quarter of a dollar more; not a bad showing considering the unusual situation which confronted the fertilizer trade.

2. That the low grades cost and valued 40 cents more this year than last year.

3. That the medium grades—the goods which undoubtedly make up the bulk of the trade in Vermont—averaged to cost \$1.25 more and to value 66 cents more.

4. That the high grades have suffered from war conditions more than the other grades, but that they have averaged to sell for 66 cents less a ton and to value 40 cents less a ton.

The statement may be ventured perhaps that in view of the extraordinary extra expense incurred by the trade due to war's alarms, the increase in price is not without justification; yet, on the other hand, it should be said that fertilizers cost more in Vermont than they should. In New York, for instance, they average to cost fully two dollars a ton less than in Vermont. For example, on the Delaware and Hudson line running from Castleton, Vermont, to Eagle Bridge, New York, paralleling and thrice crossing the western boundary line of Vermont, identical goods of the same brand name can be bought at New York points—e. g., Granville, N. Y., within a half mile of the Vermont border—at a much less sum than at Vermont points—e. g., West Pawlet, Vt., just south of Granville and within a furlong of the New York line. The freight rates are identical. Vermont farmers all along the line buy in New York on this account. Fertilizers sell in northern New York at a less price than in Franklin and Grand Isle Counties, despite the larger haul. Manufacturers advance no legitimate reason for this discrimination, save to state in general terms and without specifications that it costs more to do business in Vermont. The inspection cost excess in Vermont over New York is approximately 10 cents a ton. New York appropriates directly; Vermont assesses a brand tax. It is situations like this which lend force to the oft repeated argument in favor of cooperative buying of crude stock. As has been pointed out on page 419, neither the state purchasing agent acting for the State, nor the writer acting for the University, feels that he can afford to pay the price asked by fertilizer manufacturers for mixed goods; and it is to be hoped that increasingly the Vermont farmer will feel the same way; for it means money in his pocket.

2. FROM THE STANDPOINT OF VALUE

Let us now turn the matter about and study it from the standpoint of *worth*. These figures and proportions naturally differ somewhat from those just presented. The brands may be classified as to valuation as follows:

	Number of brands	Percent- age of total	Average valuation
Low grade, valuing at \$17 or less.....	55	32	\$14.44
Medium grade, valuing at \$17.01 to \$23.50....	63	36	19.98
High grade, valuing at \$23.51 and upwards...	55	32	27.52

The composition, selling price and valuation of the average brand of each group appears in the following table:

	Nitrogen	Available phosphoric acid	Potash	Total plant food, pounds	Average selling price	Average valuation	Selling price exceeds valuation by
Low grade	0.95	8.92	2.20	12.1	\$26.67	\$14.44	\$12.23
Medium grade	2.28	8.72	2.93	13.9	32.11	19.98	12.13
High grade	4.24	8.35	3.90	16.5	39.55	27.52	14.03

A survey of this table indicates that:

1. The proportion of nitrogen increases and of phosphoric acid lessens by regular gradations from group to group, while the potash increases somewhat in the medium and nearly doubles in the high grades as compared with the low grades.

2. The low grade goods carry more than 9 times as much phosphoric acid as they do of nitrogen and 4 times as much phosphoric acid as they do of potash. These ratios become 4 and 3 in the medium grade. The high grade fertilizers carry twice as much phosphoric acid as nitrogen or potash.

3. The medium grade goods for one-fifth advance in price over the cost of the low grade brands offer one-sixth more plant food and almost two-fifths more commercial value.

4. The high grade fertilizers for one-half advance in price over the cost of the low class goods furnish one-third more plant food and almost twice the commercial value.

5. The higher the grade the less is the margin between cost and worth. In buying the average low grade brand, one paid \$12.23 for service of one sort or another (factory and office charges, freight, selling expenses, etc.) incurred in the delivery of \$14.44 worth of plant food; when medium grade goods were bought, \$12.13 service charges placed \$19.98 worth of plant food in the buyer's hands; and when high grade goods are bought, \$14.03 service charges placed \$27.52 worth of plant food in the buyer's hands. Or, phrasing the matter another way,

THE COST OF PLACING A DOLLAR'S WORTH OF PLANT FOOD IN THE
FARMER'S HANDS WAS

- In low grade goods84 cents
- In medium grade goods61 cents
- In high grade goods51 cents

It may be worth while now to scan the prices paid for a pound each of nitrogen, of available phosphoric acid and of potash in the several grades. The next table shows this, including the average, lowest and highest costs as well as the retail cash cost of these ingredients in Boston or New York, or, in other words, their valuations.

COST OF A POUND OF PLANT FOOD IN FERTILIZERS OF VARIOUS GRADES

	MINERAL NITROGEN			ORGANIC NITROGEN			AVAIL. PHOSPHORIC ACID			POTASH (as muriate)		
	Average	Highest	Lowest	Average	Highest	Lowest	Average	Highest	Lowest	Average	Highest	Lowest
	cts.	cts.	cts.	cts.	cts.	cts.	cts.	cts.	cts.	cts.	cts.	cts.
Low grade	28.2	35.5	21.2	35.2	44.3	26.4	7.9	8.9	5.3	15.7	19.8	11.8
Medium grade.	24.5	30.5	19.8	30.6	38.0	24.7	6.2	7.7	5.0	13.7	17.0	11.1
High grade....	21.9	28.8	19.4	27.4	35.9	24.1	5.5	7.2	4.9	12.2	16.1	10.8
Seaboard retail cash prices..	15.25			19.			3.83			8.5		

The same lesson is enforced in a different way, that cheap fertilizers are the most costly. Some Vermont buyers paid 44 cents for a pound of nitrogen which they might have bought for 19 cents laid down at their doors in mixed fertilizers. They paid under similar circumstances 9 cents a pound for phosphoric acid instead of 5 cents and 20 cents for potash instead of 11 cents. They paid approximately double prices because they did not give the matter attention. The thoughtful buyer of high class goods, sold at not overhigh prices, bought plant food at figures not much in advance of valuations plus freight rates.

It ought to be said in this connection that the same brands similarly named, in different localities, as well as the same goods variously named in one locality or, indeed, in one dealer's hands, are sometimes found to sell at different prices, and apparently without good reason. A few exorbitant charges have been noted. Moreover, purchasers often fail to exercise good judgment in their choices and pay overhigh charges owing to lack of information as to what to buy and how to buy it. That this situation is largely their own fault can be claimed justly, since the State has thrown about this trade safeguards which are lacking with almost every other class of traffic. The yearly fertilizer inspection, the publication of the results of the work, the free dis-

tribution of the bulletins, the clear and concise statements as to the brands on sale, the simplicity and directness of the few fundamental facts which are the main guides as to choice and to purchase; all these are ample justification of the statement that, speaking in general terms, he who is dissatisfied with the results attained with fertilizers, so be it that weather or soil conditions favor and the seed is good, has himself to thank for it. This dissatisfaction may be due to unwise choice, that is to say the purchase of goods ill-adapted to a specific purpose; or, it may arise from the realization that one has paid an unreasonably high price in view of the grade of the goods. In either case a repetition of the experience may be avoided by the exercise of a little care as to choice. Particularly in the matter of purchase there often appears to be but little relation between price and plant food content. Thus, for example, goods guaranteed to carry uniform available phosphoric acid contents, but the highly variable nitrogen and potash contents noted below have been found in recent years selling at a uniform price at points where freight rates were not materially unlike:

Nitrogen, 33 lbs.;	potash, 40 lbs.;	nitrogen and potash, 73 lbs.
Nitrogen, 41 lbs.;	potash, 30 lbs.;	nitrogen and potash, 71 lbs.
Nitrogen, 16 lbs.;	potash, 80 lbs.;	nitrogen and potash, 96 lbs.
Nitrogen, 41 lbs.;	potash, 60 lbs.;	nitrogen and potash, 101 lbs.

Frequently two brands of the same make with identical nitrogen and phosphoric acid guaranties but with different potash guaranties (1.5 and 3 percents) are found sold at a flat price. That is to say a local agent will offer a corn fertilizer at \$30 and a potato phosphate at \$30, each containing equal amounts of nitrogen and phosphoric acid, but the latter twice as much potash as the former. This is no sin; neither is it against the law. But what well-informed buyer would choose the corn goods in preference to the potato brand? Yet doubtless many do.

One brand licensed in the early spring of 1914 was offered on Vermont markets "in order" (so wrote the manufacturer) "to meet competition with cheaper fertilizers." A special \$20 license fee was paid for the privilege. This brand sold at two points for \$29 and \$30 and "valued" at barely \$11. It furnished only 38 cents' worth of plant food for a dollar, the lowest figure in years. The same local agent who sold it at \$30 also sold for \$30 another brand specially named for the same crop. These latter goods carried 2.5 times as much nitrogen, half again as much potash and a percent more available phosphoric acid. He also sold at \$31 another brand manufactured by the company that

pecially licensed these competing goods, carrying twice the nitrogen content, ten times the potash content, and one percent more available phosphoric acid than this new comer. For this extra dollar bill was furnished 16 pounds nitrogen, 20 pounds available phosphoric acid, and 180 pounds potash, plant food worth at the seaboard approximately \$11. The guarantied monetary equivalent of the one brand was barely \$10, of the other \$21; and they sold respectively at \$30 and at \$31. And both, save the mark, were "potato fertilizers," one apparently well adapted to its purpose, the other a palpable absurdity, a travesty. And yet there must be several farmers who buy this brand so low in plant food values, so costly in proportion to its power of rendering service; for the manufacturer reports a competitive demand and paid an extra \$20 fee for the selling privilege. Another absurdity disclosed in connection with its sale is that another brand made by the same company, absolutely identical in every respect, in guaranty figure for figure, and in analyses almost figure for figure, sold for \$2 a ton more than the other and both in the one agent's hands. The competing goods in this location which, in view of the manufacturer whose action is now under discussion, necessitated the special license fee, seems to have been a brand which carried the same nitrogen contents and four times as much potash and a percent more available phosphoric acid, and which sold at the same price. And this absurd brand again has been licensed for sale in 1915, and history is repeating itself.

There is nothing illegal about these practices. A manufacturer may name his goods as he pleases, and may, as some do, name, rename and name again and again identical goods and sell them under these various names. He may charge what he pleases, a low price or a high one, as high as he can get. The law neither can nor ought it to reach him. It is for the buyer to beware, to exercise some forethought. Such episodes are now much less common than formerly was the case, for buyers now purchase in a more discriminating manner than of old; and yet one manufacturer licenses for sale in Vermont this year only low grade brands and caters only to the hoky-poky trade.

The non-nitrogenous brands, 11 of which are licensed, being relatively cheap are quite popular and somewhat widely sold. As a class they furnish costly plant food. As sold this year in Vermont they average to offer only 55 cents' worth of plant food for a dollar. When one has ample home supplies of nitrogen, non-nitrogenous goods may prove advisable purchases; but commercially they are usually expensive plant food.

3. AS BETWEEN MANUFACTURERS

Two companies averaged to charge 43 cents for placing a dollar's worth of plant food in the buyer's hands; another company asked 96 cents for placing a dollar's worth of plant food in the hands of Vermont farmers. In one case a dollar bought 70 cents' worth of plant food, in the other 51 cents' worth; or, stating it yet another way, the buyer of certain low priced brands paid \$1.96 and received therefor a dollar's worth of plant food. His neighbors paid in some cases as low as \$1.43 for a dollar's worth. Which made the wiser purchase? It is not difficult for anyone to apply this test before purchase. Thus, for example: Selling price, \$30; guaranty, nitrogen 2%; soluble, reverted and insoluble phosphoric acids, 6, 3 and 1%; potash 3%. $2 \times 20 \times .19 = 7.60$.¹ $6 \times 20 \times .04 = 4.80$. $3 \times 20 \times .035 = 2.10$. $1 \times 20 \times .02 = 0.40$. $3 \times 20 \times 0.85 = 5.10$. $\$7.60 + \$4.80 + \$2.10 + \$0.40 + \$5.10 = \20.00 . $\$20.00 \div 30 = 67^2$; or $30 \div 20.00 = 1.50$.³ Fifty cents' service charge to cover the cost of placing at the depot a dollar's worth of plant food; 67 cents' worth of plant food received by the buyer for his dollar.

4. ELEMENTS DETERMINING THE PRICE OF A COMMERCIAL FERTILIZER

Many elements enter into the determination of the cost of a commercial fertilizer as it is usually bought by the farmer from a local dealer in relatively small amounts and on time. They include:

1. *Assembling*. The original wholesale cost of the crude stocks or ingredients to the manufacturer, who secures nitrate of soda from Chili, potash salts from Germany, pyrites for the manufacture of sulphuric acid from many localities in this and other countries, phosphate rock from Florida, South Carolina or Tennessee, sulphate of ammonia from Europe or from various points in this country, organic ammoniates from all sorts and conditions of places, from near at hand and from the ends of the earth. This original cost must of course cover the cost of mining and manufacture, of freight to the factory and the overhead charges incident to manufacture, shipping and jobbing.

2. *Mixing*. The cost of mixing, including the manufacture of sulphuric acid, the expense of grinding phosphate rock, bones, etc.,

¹I. e., 2% (or 2 pounds per 100) nitrogen, multiplied by 20, gives the pounds of nitrogen in one ton, which, multiplied by the trade value of a pound of organic nitrogen (19 cents), affords the valuation of the guaranty of nitrogen, \$7.60. The other calculations are similarly made.

²Valuation divided by cost equals worth of plant food per dollar spent.

³Cost divided by valuation indicates service charge paid for a dollar's worth of plant food bought.

the commingling in the requisite proportions of the several ingredients, their storage until dry, their regrinding, bagging and loading.

3. *Mixing.* The overhead cost on the charges which are necessarily connected with the assembling and the mixing of the plant food, covering such items as interest on investment, insurance, taxes, depreciation of the manufacturing plant, certain office charges, etc.

4. *Transportation.* Freight from factory to railroad station.

5. *Selling.* The overhead costs and charges inevitably connected with the sale of mixed fertilizers, covering such items as commissions to agents and dealers, interest charges on long credits, bad debts, advertising, and, finally, profits.

Now every one of these charges is a perfectly legitimate one properly incident to the sale of plant food in the mixed condition. They explain why a local retail selling price on time must needs be far in excess of the station valuation which covers only the retail seaboard value of the equivalent amounts of plant food.

A farmer who wishes to make some calculation as to these matters may perhaps figure as follows:

The XYZ brand cost me \$32.50, payments to be made November first. The station valuation is \$20.50, being the sum of the several valuations of its nitrogen, phosphoric acid and potash contents. This represents the reasonable retail cash cost at Boston and New York of plant food (item 1 above). The cost of mixing and bagging, including the bags, may be assumed (it is an assumption, only this and nothing more, for the costs must vary more or less in large as compared with small factories) at \$2.50 a ton (items 2 and 3 above). The freight rate to my railroad station in less than carload lots is \$4.30 a ton, (item 4 above). The overhead charges in connection with sales may be assumed (again a bald assumption) at 20 percent of the f. o. b. factory price. $\$20.50 + \$2.50 \times .20 = \$4.60$ (item 5 above). $\$20.50 + \$2.50 + \$4.30 + \$4.60 = \$31.90$, which is an approximation to the selling price on time. In making such a calculation each individual farmer can definitely determine and know items 1 and 4 (valuation and freight rate). The assumption of 20 percent of f. o. b. factory price for selling charges (item 5) is probably a fairly safe one. The main doubtful factor is the mixing charge (items 2 and 3).

It is not to be expected that such a calculation will give an exact figure or precisely represent the price which may be charged in a given locality. Divers conditions of the market, competition, etc., introduce disturbing factors and induce minor variations. But it may

prove serviceable in a general way, if not interpreted too literally, in connection with the time purchases of relatively small lots. It goes without saying that goods can be bought for spot cash in large quantities at much lower figures.

A concrete illustration of this situation may be offered. This spring the Station bought 1,300 pounds of nitrate of soda, 3,200 pounds of tankage, 11,000 pounds of acid phosphate and 1,600 pounds of muriate of potash. The delivered cost was \$223.89. The average complete fertilizer sold on time delivered in small lots sold this year at \$33.06 per ton and contained about 2.3 percent nitrogen, 8.7 percent available phosphoric acid, and 2.5 percent potash. Let us make a comparison of the relative amounts of plant food bought for the same sum, i. e., \$33.06.

Delivered	Available		Potash
	Nitrogen	phosphoric acid	
In mixed goods on time	46	174	50
In crude stock delivered for cash.....	56	280	118

Any farmer who appreciates that 56 is larger than 46, who realizes that 280 is in excess of 174, and can see that 118 is a somewhat greater figure than is 50, ought to realize which is the better purchase. The only extra investment the Station had to make was the mixing of the goods, which doubtless cost somewhere between fifty cents and a dollar a ton. Several of the state institutions bought on the same favorable basis. The station budget is a considerable one, and the State of Vermont has an income of much more than a million dollars yearly; but neither the state purchasing agent, acting for the State, nor the writer acting for the Station, feels that he can justify the purchase of plant food for State and Station save at rock bottom prices and in accordance with modern methods.

The individual farmer does not often buy nine tons. But would it not be worth his while to combine with neighbors in purchasing? Combined orders, either of crude stock or mixed goods, using borrowed money if necessary, would result in marked savings as compared with individualistic purchase on time. Many farmers in the counties served by county agents now buy crude stock. The Station, acting for the State Extension Service, took many samples of crude stock in 1914 at various points throughout the State and analyzed them. They represented goods bought by county farmers' associations and private individuals. Practically without exception they were as good as they were said to be. The farmers received much more plant food for their money than did the average buyer of commercial fertilizer, more

probably than did almost any buyer of high grades; they know more about fertilizers than they used to know; and the field results were highly satisfactory.

V. OBSERVANCE OF THE FERTILIZER LAW

LIST OF LICENSED COMMERCIAL FERTILIZERS

The following companies have paid licenses on the 173 brands specified on this and the next few pages, being the entire number of licensed brands save the six listed on page 391, which were not found on sale by the station sampling agents. This list also shows the points at which samples were drawn and the laboratory sample numbers referring to the analyses on pages 428-439.

AMERICAN AGRICULTURAL CHEMICAL COMPANY, 2 Rector Street,
New York, N. Y.

- G 1 Extra Special Grass and Garden Mixture; North Bennington.*
- G 2 Grass and Lawn Topdressing; North Bennington.*
- M 1 Grass and Oats; Georgia.*
- A 1 Special AA Potato Grower; Randolph.*
- A 3 Special General Crop Grower; West Haven.*
- A 2 Special High Grade Fertilizer; St. Albans.*
- K 3 Special Vegetable and Potato Manure; St. Johnsbury Center.*
- M 2 Special XXX Phosphate and Potash; Swanton.*
- G 3 Topdresser; Jericho.*
- (Bradley Fertilizer Company brands).
- M 3 Alkaline Bone with Potash; Sheldon.*
- A 4 Corn Phosphate; Bethel.*
- A 5 Eclipse Phosphate for All Crops; Montpelier.*
- G 16 Extra Complete Manure; Brattleboro.*
- A 7 Potato Fertilizer; Bethel.*
- J 1 Revised High Grade Potato and Root Special; Danville.*
- G 4 Special Circle Brand Bone and Potash; North Troy.*
- G 5 Special Complete Manure for Corn and Grain; Glover.*
- A 8 Special Complete Manure for Potatoes and Vegetables; Randolph.*
- G 6 Special Complete Manure for Topdressing Grass and Grain; Chester Depot.*
- E 9 Special Potato Manure; North Troy.*
- A 6 XL Superphosphate of Lime; Randolph.*

(Cleveland Dryer Company brands).

G 7 *General Crop Fertilizer*; Enosburgh Falls.

G 8 *Potato Phosphate*; Enosburgh Falls.

G. 9 *Superphosphate*; Irasburgh.

(Crocker Fertilizer and Chemical Company brands).

A 10 *Ammoniated Corn Phosphate*; St. Albans.

A 11 *New Rival Ammoniated Superphosphate*; Ira.

A 12 *Potato Hop and Tobacco Fertilizer*; St. Albans.

A 13 *Special Potato Fertilizer*; Ira.

(Darling Fertilizer Company brands).

K 4 *Farm Favorite*; South Fairlee.

K 5 *Special Blood, Bone and Potash*; Putney.

G 10 *Special General Fertilizer*; Irasburgh.

(Great Eastern Fertilizer Company brands).

A 14 *Northern Corn Special*; Georgia.

A 16 *Potato Manure*; Bethel.

A 15 *Revised General Fertilizer*; Georgia.

G 11 *Special High Grade Potato Fertilizer*; Moretown.

(Pacific Guano Company brands).

B 1 *Nobsque General Guano*; Randolph.

G 12 *Potato Special*; Wallingford.

B 2 *Soluble Pacific Guano*; Randolph.

(Quinnipiac Company brands).

J 2 *Corn Manure*; Sheldon.

B 3 *Potato Phosphate*; St. Albans.

G 13 *Special Market Garden Manure*; Brattleboro.

(Read Fertilizer Company brands).

B 4 *Farmers' Friend Superphosphate*; Swanton.

B 6 *Practical Fertilizer*; St. Albans.

B 5 *Special High Grade Farmers' Friend Superphosphate*; West Haven

M 4 *Sure Catch Fertilizer*; Highgate.

(Williams and Clark Fertilizer Company brands).

B 7 *Americus Ammoniated Bone Superphosphate*; St. Albans.

B 8 *Americus Corn Phosphate*; Ira.

B 9 *Americus High Grade Special for Potatoes and Root Crops*; Ira.

B 10 *Americus Potato Manure*; Randolph.

B 11 *Royal Bone Phosphate*; Ira.

B 12 *Special Potato Phosphate*; Ira.

B 13 *Special Prolific Crop Producer*; Montpelier.

ARMOUR FERTILIZER WORKS, 930-938 Equitable Building, Baltimore, Md.

- F 1 All Soluble; Bellows Falls.*
- R 7 All Soluble; Bellows Falls.*
- G 14 Five-Eight-Four; Brattleboro.*
- G 15 Four-Eight-Three; Brattleboro.*
- F 2 Grain Grower; Bellows Falls.*
- M 5 Phosphate and Potash; Brattleboro.*
- L 1 Ten-Six-Three; Hartford.*
- F 3 Three-Eight-Three; Pownal.*
- R 8 Three-Eight-Three; Bellows Falls.*

BOWKER FERTILIZER COMPANY, 43 Chatham Street, Boston, Mass.

- L 3 All Round Fertilizer; Windsor.*
- C 1 Brighton Phosphate; Castleton.*
- C 2 Corn Phosphate; Castleton.*
- C 3 Farm and Garden Phosphate; Randolph.*
- H 1 Highly Nitrogenized Mixture; Newport.*
- H 2 Hill and Drill Phosphate; Bennington.*
- H 3 Potato and Vegetable Fertilizer, revised; Bakersfield.*
- C 4 Potato and Vegetable Phosphate; St. Albans.*
- J 3 Square Brand Fertilizer; Winooski.*
- C 5 Stockbridge General Crop Manure; Bethel.*
- C 6 Stockbridge Cereal Manure; St. Albans.*
- C 7 Stockbridge Early Crop Manure; Randolph.*
- C 8 Sure Crop Phosphate; Randolph.*

J. F. BROMLEY, Granville, N. Y.

- H 4 Corn and Potato; East Berkshire.*
- M 6 Grain and Grass; Montpelier.*
- H 5 Special Corn Fertilizer; Bethel.*
- H 6 Special Potato Fertilizer; Montpelier.*

BURLINGTON RENDERING COMPANY, North Avenue, Burlington, Vt.

- B 14 Animal Fertilizer; Barre.*
- B 15 Grain Fertilizer; South Royalton.*
- B 16 Special Potato Fertilizer; Swanton.*
- H 7 Vegetable Fertilizer; Bristol.*

COE-MORTIMER COMPANY, Chambers Street, New York, N. Y.

- K 6 *Blood, Bone and Potash (Special)*; North Montpelier.
- K 7 *Blue Brand Excelsior Guano*; North Montpelier.
- J 4 *Columbian Corn and Potato Fertilizer (Special)*; Bellows Falls.
- F 4 *Excelsior Potato Fertilizer (Special)*; Morrisville.
- M 7 *Famous Prize Brand Grain and Grass Fertilizer*; Swanton.
- F 5 *High Grade Ammoniated Superphosphate (Special)*; Swanton.
- F 6 *New Englander Special (Revised)*; Bethel.
- L 2 *Prolific Crop Producer*; Underhill.
- F 7 *Special Grass Topdressing (Revised)*; Derby.
- F 8 *Standard Potato Fertilizer (Special)*; Swanton.
- F 9 *XXX Ammoniated Phosphate*; West Rupert.

ESSEX FERTILIZER COMPANY, 39 North Market Street, Boston, Mass.

- J 5 *Complete Grass Fertilizer for Topdressing and Seeding*; Barton.
- F 10 *Complete Manure for Corn, Grain and Grass*; East Berkshire.
- F 11 *Complete Manure for Potatoes, Roots and Vegetables*; Hyde Park.
- F 12 *Grain, Grass and Potato Fertilizer*; Enosburgh Falls.
- F 13 *Market Garden and Potato Manure*; Randolph.
- F 14 *XXX Fish and Potash for All Crops*; Jericho.

INTERNATIONAL AGRICULTURAL CORPORATION,

BUFFALO FERTILIZER WORKS, 812 Marine Bank Building, Buffalo, N. Y.

- E 1 *Farmers' Choice*; Enosburgh Falls.
- R 3 *Farmers' Choice*; Middlebury.
- J 6 *Five-Eight-Four*; Springfield.
- J 7 *High Grade Manure*; Springfield.
- E 2 *New England Special*; St. Albans.
- E 3 *One-Eight-Two*; Johnson.
- E 4 *Three-Eight-Four*; Proctorsville.
- R 4 *Three-Eight-Four*; Barton.
- E 5 *Topdresser*; Johnson.
- R 5 *Topdresser*; Plainfield.
- M 8 *Twelve and Two*; Springfield.
- E 6 *Vegetable and Potato*; East Berkshire.

LISTERS' AGRICULTURAL CHEMICAL WORKS, Lister Avenue, Newark,
N. J.

- M 9 *Grain and Grass Fertilizer*; Ludlow.

- E 7 Revised Corn and Potato Fertilizer; Ludlow.*
- K 8 Revised High Grade Topdresser; North Troy.*
- E 8 Revised Potato Manure; Johnson.*
- E 9 Revised Vermont Corn and Potato Fertilizer; North Troy.*
- E 10 Success Fertilizer; Stowe.*

LOWELL FERTILIZER COMPANY, 44 North Market Street, Boston, Mass.

- C 9 Animal Brand for All Crops; St. Albans.*
- C 10 Bone Fertilizer for Corn, Grain, Grass and Vegetables; South Royalton.*
- H 8 Cereal Fertilizer; Shaftsbury.*
- H 9 Corn and Vegetable Manure; Brattleboro.*
- C 11 Empress Brand for Corn, Potatoes and Grain; St. Albans.*
- C 12 Potato Manure; Ira.*
- K 15 Potato Phosphate; Proctorsville.*
- H 10 Special Grass Mixture; Underhill.*
- H 11 Sterling Phosphate; Orleans.*
- H 12 Superior Fertilizer; Essex Junction.*

NATIONAL FERTILIZER COMPANY, 92 State Street, Boston, Mass.

- K 9 Ammoniated Bone Phosphate; East Fairfield.*
- K 10 Special Complete Grass; Ludlow.*
- K 11 Special Eureka Potato Fertilizer; Fairfield.*
- K 12 Special Potato Phosphate; Norwich.*
- K 13 Tobacco Special Revised (Sulphate); Westminster.*

NEW ENGLAND FERTILIZER COMPANY, 40A North Market Street,
Boston, Mass.

- C 13 Complete Manure; Randolph.*
- C 14 Corn and Grain Fertilizer; Poultney.*
- R 1 Corn and Grain Fertilizer; Brandon.*
- C 15 Corn Phosphate; Poultney.*
- C 16 High Grade Potato Fertilizer; Ira.*
- H 13 Peerless Fertilizer; Bakersfield.*
- H 14 Potato Fertilizer; Poultney.*
- H 15 Superphosphate for All Crops; Newfane.*

PARMENTER AND POLSEY FERTILIZER COMPANY, 40 North Market
Street, Boston, Mass.

- F 15 Corn and Grain Fertilizer; St. Albans.*

F 16 Plymouth Rock Brand Fertilizer for All Crops; St. Albans.

H 16 Potato Fertilizer; St. Albans.

READING BONE FERTILIZER COMPANY, 32-34 North Sixth Street,
Reading, Pa.

M 10 Alkaline Phosphate and Potash; Bakersfield.

E 11 All Crop Special; Rupert.

*E 16 Truck, Fruit, Tree, Vine, Potato and Tobacco Grower;
St. Albans.*

J 8 Gilt Edge Potato and Tobacco Grower; East Burke.

E 13 Never Fail Crop Grower; West Haven.

E 14 Prize Winner; St. Albans.

E 15 Special Grain and Grass Producer; West Haven.

J 9 Potato and Tobacco Manure; Bakersfield.

*E 16 Truck, Fruit, Tree, Vine, Potato and Tobacco Grower;
St. Albans.*

ROGERS AND HUBBARD COMPANY, Middletown, Conn.

J 10 All Soils—All Crops Phosphate; South Vernon.

D 12 Complete Phosphate; St. Albans.

R 3 Complete Phosphate; St. Albans.

D 13 Fertilizer for Oats and Topdressing; Barre.

J 11 Fertilizer for Seeding Down and Fruit; North Bennington.

D 14 Potato Phosphate; Clarendon.

D 15 Soluble Corn and General Crops Manure; St. Albans.

D 16 Soluble Potato Manure; Clarendon.

J 12 Soluble Tobacco Manure; Bradford.

F. S. ROYSTER GUANO COMPANY, 1255 Calvert Building, Baltimore, Md.

D 8 Favorite Compound; Highgate.

K 14 Parfait Compound; Essex Center.

D 9 Truckers' Delight; St. Albans.

D 10 Utopia Compound; St. Albans.

D 11 Wheat, Oats and Barley Fertilizer; Highgate.

J. W. SANBORN, Pittsfield, N. H.

*J 13 Prof. Sanborn's Chemical Fertilizer for Grass and Grain;
Waitsfield.*

*J 14 Prof. Sanborn's Chemical Fertilizer for Use in Hill and Drill;
Moretown.*

- J 15 Prof. Sanborn's Chemical Fertilizer for Potatoes and Corn; Bakersfield.*

SANDERSON FERTILIZER AND CHEMICAL COMPANY, Box 172, New Haven, Conn.

- D 4 Atlantic Coast Bone Fish and Potash (Revised); Castleton.*
D 5 Corn Superphosphate for Corn and Grain; Proctorsville.
D 6 Potato Manure (Revised); Cambridge.
D 7 Special with Potash (Revised); Castleton.

VIRGINIA-CAROLINA CHEMICAL COMPANY, 24 Broad St., New York, N. Y.

- D 1 Ammoniated Potash Compound; Georgia.*
M 11 Little Giant Fertilizer with two percent Potash; Lyndonville.
J 16 Owl Brand Potato and Truck Fertilizer with four percent Potash; Groton.
D 3 Special Corn and Grain Grower; Morrisville.
K 1 Star Brand Potato and Vegetable Compound with four percent Potash; Hardwick.
D 2 Universal Fertilizer for All Crops; Morrisville.
K 2 XXX Fish and Potash; Hardwick.

CONCERNING THE TABLES ON PAGES 428-439

These tables, from the point of view of the execution of the law, form the essential part of the bulletin. Therein are displayed side by side what the fertilizer manufacturer says he will furnish and what he does furnish, the one in *italics*, the other in **black face**. Furthermore all the details are given in order that the buyer may judge not only how much or how little plant food he gets for his money but how good or how inferior it is and what parts are good and what less good. While it is doubtless true that most buyers pay no attention to the work of the control, many who have done so have profited thereby in getting a larger return in plant food for a dollar spent as a result of their study of the matter. And in order that such as may wish to grasp the full purport of these tables may be enabled to do so, there has been published from time to time brief explanatory matter, and several years ago, a series of very full, almost painfully full, explanations of the meanings and significance of each piece of data was printed in bulletin 143. And there appears in this issue yet further explanation as to the nitrogen columns which during the past five years have been thoroughly differentiated.

In brief it may be said that the parallel **black face** and *italic* columns are the most serviceable means of comparing promises and actualities so far as the quantity of plant food is concerned; and that the other figures, exclusive of the valuation, help one to determine more particularly the quality of a given fertilizer.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid	Found	Guaranteed	Valuation of potash
American Agricultural Chemical Co.																			
Extra Sp. Grass & Garden	3.81	3.01	0.32	0.81	0.49	8.44	8.23	\$26.92	1.80	4.80	0.42	7.02	7.	6.60	6.	\$4.97	4.06	4.	\$6.90
Grass and Lawn Topdress.	1.91	1.49	0.28	0.36	0.24	4.28	3.91	13.69	3.28	2.85	0.38	6.31	6.	5.98	5.	4.63	2.19	2.	3.72
Grass and Oats Fertilizer	...	...	...	...	...	...	...	...	7.22	4.22	0.74	12.18	12.	11.44	11.	9.03	2.34	2.	3.98
Sp. A. A. Potato Grower	1.49	1.11	0.28	0.71	0.43	4.02	3.7	13.31	5.28	4.73	1.23	11.24	11.	10.01	10.	8.02	3.97	4.	6.75
Sp. General Crop Grower	0.57	0.43	0.21	0.35	0.21	1.77	1.65	5.97	3.84	4.25	1.27	9.26	9.	8.09	8.	6.55	2.52	2.	4.30
Sp. High Grade Fertilizer	1.04	0.94	0.28	0.46	0.28	2.00	2.88	9.91	4.32	3.37	1.93	10.12	9.	8.19	8.	6.94	4.32	4.	7.34
Sp. Vegetable and Potato	0.49	0.42	0.40	0.49	0.27	2.07	1.65	7.18	4.44	5.31	1.37	11.12	11.	9.75	10.	7.82	2.23	2.	3.79
Sp. XXX Phos. and Potash	...	...	...	...	...	...	...	...	11.50	3.85	0.89	16.24	15.	15.25	14.	12.25	1.72	2.	2.92
Topdresser	2.72	0.95	0.46	0.40	0.29	4.52	4.94	15.47	1.92	6.35	0.37	8.04	8.	8.27	7.	6.13	2.02	3.	5.13
Bradley Fertilizer Co. brands																			
Alk. Bone with Potash	...	...	...	...	...	...	...	...	7.56	3.98	0.79	12.33	12.	11.54	11.	9.16	2.00	2.	3.40
Corn Phosphate	0.59	0.46	0.49	0.40	0.27	2.21	2.06	7.61	4.52	3.83	1.81	10.16	9.	8.35	8.	7.02	1.90	1.5	3.06
Eclipse Phosphate	0.30	0.21	0.28	0.26	0.18	1.23	1.03	4.29	3.48	4.85	1.00	9.23	9.	8.33	8.	6.57	2.18	2.	3.71
Extra Complete Manure	1.25	1.00	0.45	0.51	0.28	2.49	2.29	11.56	5.64	4.82	1.14	11.40	11.	10.26	10.	8.20	2.90	4.	6.78
Potato Fertilizer	0.42	0.44	0.54	0.40	0.27	2.07	2.08	7.22	4.28	4.18	1.96	10.42	9.	8.46	8.	7.13	2.90	3.	5.44
Revised H. G. Potato, Root	0.46	0.51	0.32	0.36	0.19	1.84	1.65	6.27	4.10	5.98	1.36	11.44	11.	10.08	10.	8.01	2.12	2.	3.62
Special Circle Bone, Pot.	0.58	0.45	0.18	0.41	0.26	1.88	1.65	6.36	3.30	4.94	1.22	9.46	9.	8.24	8.	6.59	2.06	2.	3.50
Sp. Complete Corn Gr.	1.19	1.13	0.19	0.64	0.31	2.46	3.29	11.40	6.48	3.95	0.64	11.07	11.	10.43	10.	8.21	2.86	4.	6.56

†See definition page 393.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN					PHOSPHORIC ACID							POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water organic	Inactive water organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†
American Agricultural Chemical Co.																			
<i>Bradley Fertilizer Co. brands—Cont.</i>																			
Sp. Complete Potato, Veg.	1.05	1.04	0.54	0.59	0.32	3.54	3.29	\$11.88	4.60	3.88	1.92	10.40	9.	8.48	8.	\$7.17	4.90	4.	\$7.14
Sp. Complete Topdressing	3.00	1.35	0.33	0.45	0.27	5.40	4.94	17.18	4.44	3.82	0.74	9.00	8.	8.36	7.	6.52	3.08	3.	5.24
Special Potato Manure	0.91	0.86	0.25	0.44	0.23	2.69	2.47	8.90	4.08	4.32	1.60	10.00	9.	8.40	8.	6.92	3.10	3.	5.27
XXL Superphosphate	0.35	1.04	0.35	0.65	0.40	2.79	2.47	9.59	4.80	4.24	1.80	10.84	10.	9.04	9.	7.53	2.13	2.	3.62
<i>Cleveland Dryer Co. brands</i>																			
General Crop Fertilizer	...	0.26	0.35	0.40	0.27	1.98	1.03	4.69	3.50	4.58	1.87	9.95	9.	8.08	8.	6.76	2.12	2.	3.60
Potato Phosphate	0.60	0.45	0.63	0.41	0.28	2.37	2.06	8.21	4.30	4.65	1.82	10.77	9.	8.95	8.	7.43	3.32	3.	5.47
Superphosphate	0.60	0.45	0.53	0.42	0.28	2.38	2.06	7.86	3.76	4.38	1.78	9.92	9.	8.14	8.	6.79	1.53	1.5	2.60
<i>Crocker Fertilizer & Chemical Co. brands</i>																			
Ammo. Corn Phosphate	0.66	0.39	0.40	0.46	0.28	2.19	2.06	7.52	3.20	4.92	1.56	9.68	9.	8.12	8.	6.62	1.70	1.5	2.89
New Rival Ammo. Super.	...	0.11	0.35	0.45	0.27	1.18	1.03	4.41	4.60	3.99	1.52	10.11	9.	8.59	8.	7.08	2.31	2.	3.93
Potato, Hop and Tobacco	0.52	0.46	0.60	0.43	0.27	2.38	2.06	7.93	4.24	4.56	1.90	10.70	9.	8.80	8.	7.34	2.81	3.	4.78
Special Potato Fertilizer	1.12	1.09	0.44	0.59	0.32	3.56	3.29	11.87	4.24	3.78	2.08	10.10	9.	8.02	8.	6.87	4.69	4.	7.97
<i>Darting Fertilizer Co. brands</i>																			
Farm Favorite	0.64	0.52	0.41	0.58	0.26	2.41	2.06	8.28	3.62	5.06	1.55	10.23	9.	8.68	8.	7.06	3.10	3.	5.27
Special Blood, Bone, Pot.	1.48	1.40	0.29	0.69	0.28	4.14	4.11	13.57	5.42	5.12	0.58	11.12	10.	10.54	9.	8.15	4.07	4.	6.92
Special General Fertilizer	...	0.21	0.32	0.41	0.24	1.18	1.03	4.34	3.24	4.69	2.16	10.09	9.	7.96	8.	6.73	2.07	2.	3.52

†See definition page 393.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble			Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†
									Reverted	Insoluble	Insoluble								
<i>American Agricultural Chemical Co.</i>																			
<i>Great Eastern Fertilizer Co. brands</i>																			
Northern Corn Special	0.71	0.34	0.40	0.41	0.28	2.14	2.06	\$7.32	3.74	4.78	1.34	9.96	9.	8.52	8.	\$6.88	1.80	1.5	\$2.72
Potato Manure	0.63	0.77	0.23	0.34	0.24	2.31	2.06	7.36	4.00	4.46	1.30	9.76	9.	8.46	8.	6.84	3.39	3.	5.59
Revised General Fertilizer	0.17	0.13	0.25	0.28	0.21	1.04	0.82	3.72	4.42	4.62	1.60	10.44	9.	9.04	8.	7.41	2.04	2.	3.47
Special H. G. Potato	1.19	0.97	0.35	0.66	0.41	3.58	3.29	11.98	3.68	4.72	1.60	10.00	9.	8.40	8.	6.88	4.06	4.	6.90
<i>Pacific Guano Co. brands</i>																			
Nobsque General Guano	...	0.36	0.23	0.35	0.25	1.19	1.03	4.27	3.76	4.69	2.02	10.47	9.	8.45	8.	7.10	2.30	2.	3.91
Potato Special	0.72	0.61	0.21	0.39	0.26	2.19	2.06	7.32	3.92	4.99	1.40	10.31	9.	8.91	8.	7.19	3.14	3.	5.34
Soluble Pacific Guano	0.72	0.53	0.30	0.50	0.31	2.36	2.06	8.02	4.12	4.44	1.72	10.38	9.	8.56	8.	7.10	1.66	1.5	2.82
<i>Quinsigamont Co. brands</i>																			
Corn Manure	0.70	0.27	0.45	0.43	0.27	2.12	2.06	7.31	3.44	4.91	1.88	10.28	9.	8.35	8.	6.94	1.45	1.5	2.47
Potato Phosphate	0.55	0.51	0.53	0.40	0.25	2.24	2.06	7.71	4.88	3.97	1.90	10.75	9.	8.85	8.	7.44	3.24	3.	5.51
Special Market Garden	1.21	0.96	0.29	0.55	0.43	3.44	3.29	11.44	3.72	4.73	1.15	9.60	9.	8.45	8.	6.75	4.52	4.	7.68
<i>Read Fertilizer Co. brands</i>																			
Farmers' Friend Super.	0.79	0.16	0.47	0.51	0.28	2.31	2.06	7.66	3.20	5.25	1.90	10.35	9.	8.45	8.	6.99	3.18	3.	5.41
Practical Fertilizer	...	0.16	0.45	0.35	0.25	1.21	1.03	4.49	3.04	5.11	2.05	10.20	9.	8.15	8.	6.83	2.30	2.	3.74
Special H. G. Far's Friend	1.20	1.05	0.52	0.47	0.23	3.47	3.29	11.50	6.00	4.50	1.32	11.82	11.	10.50	10.	8.48	3.96	4.	6.73
Sure Catch Fertilizer	...	...	...	...	...	...	...	....	5.08	5.04	1.08	11.20	11.	10.12	10.	8.02	3.07	2.	3.52

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble	Active water organic	Inactive water organic	Total found	Total guaranteed	Valuation of nitro- gen†	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available	Valuation of phos- phoric acid‡	Found	Guaranteed	Valuation of potash†
American Agricultural Chemical Co.																			
<i>Willkams & Clark Fertilizer Co. brands</i>																			
Amer. Ammo. Bone Super.	0.63	0.53	0.70	0.46	0.30	2.62	2.47	\$9.08	4.28	5.72	1.50	11.50	10.	10.00	9.	8.02	2.18	2.	\$3.71
Amer. Corn Phosphate	0.75	0.67	0.24	0.39	0.21	2.96	2.06	7.52	4.04	4.67	1.88	10.59	9.	8.71	8.	7.25	1.69	1.5	2.87
Amer. H. G. Sp. Pot., Root	1.28	1.02	0.23	0.66	0.32	3.51	3.29	11.60	4.40	4.42	1.52	10.34	9.	8.82	8.	7.22	3.96	4.	6.56
Amer. Potato Manure	0.65	0.62	0.29	0.45	0.27	2.98	2.06	7.71	4.50	4.28	1.62	10.40	9.	8.78	8.	7.25	3.92	3.	5.47
Royal Bone Phosphate	...	0.14	0.38	0.32	0.23	1.07	1.03	3.96	3.02	5.08	2.06	10.16	9.	8.10	8.	6.80	2.15	2.	3.66
Special Potato Phosphate	0.98	0.81	0.32	0.41	0.22	2.74	2.47	9.06	4.40	4.28	1.12	9.90	9.	8.68	8.	6.97	3.08	3.	5.15
Special Prolific Crop Prod.	...	0.14	0.34	0.20	0.15	0.83	0.82	3.05	3.48	4.78	1.10	9.36	9.	8.26	8.	6.57	1.19	1.	2.02
Armour Fertilizer Works																			
All Soluble	...	1.17	0.49	0.67	0.47	2.80	2.88	9.82	3.52	3.91	1.67	9.10	8.5	7.48	8.	6.23	3.90	4.	6.63
All Soluble	0.64	0.31	0.65	0.82	0.62	3.04	2.88	10.82	5.98	2.05	1.81	9.84	8.5	8.03	8.	6.94	3.78	4.	6.43
Five, Eight, Four	...	1.22	0.80	1.25	0.68	3.95	4.11	14.15	3.56	4.28	1.60	9.44	8.5	7.94	8.	6.49	3.46	4.	6.22
Four, Eight, Three	...	1.24	0.58	0.98	0.62	3.42	3.29	12.12	3.92	3.80	1.66	9.88	8.5	7.72	8.	6.46	3.42	3.	5.81
Grain Grower	...	0.58	0.29	0.48	0.35	1.70	1.65	6.06	3.72	4.24	0.83	8.79	8.5	7.96	8.	6.28	2.19	2.	3.72
Phosphate and Potash	...	...	...	...	...	...	...	...	10.92	1.42	0.46	12.80	12.5	12.34	12.	9.91	2.00	2.	3.40
Ten, Six, Three	...	6.93	0.09	-0.14	...	7.16	8.23	22.35	5.52	0.89	0.60	7.01	6.5	6.41	6.	5.28	14.74	3.	8.57
Three, Eight, Three	...	0.67	0.41	0.70	0.46	2.24	2.47	8.05	4.76	3.01	1.45	9.32	8.5	7.77	8.	6.50	3.67	3.	6.24
Three, Eight, Three	...	0.63	0.52	0.77	0.50	2.42	2.47	8.75	4.00	3.62	2.00	9.62	8.5	7.62	8.	6.53	3.30	3.	5.51

†Potash partly as sulphate. ‡See definition, page 393.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water organic	Inactive water organic	Total found	Total guaranteed	Valuation of nitrogen	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phosphoric acid†	Found	Guaranteed	Valuation of potassium
Bowker Fertilizer Co.																			
All Round Fertilizer	0.79	0.91	0.34	0.36	0.17	2.57	2.47	\$8.50	5.06	2.94	2.03	10.08	9.	8.00	8.	\$6.92	2.66	3.	\$4.52
Brighton Phosphate	0.25	0.16	0.13	0.21	0.18	0.96	0.82	3.23	3.74	4.62	1.04	9.40	9.	8.86	8.	6.64	1.05	1.	1.79
Corn Phosphate	0.55	0.47	0.16	0.38	0.25	1.81	1.65	6.11	4.00	4.98	1.10	10.06	9.	8.96	8.	7.13	2.68	2.	4.56
Farm and Garden Phos.	0.53	0.54	0.12	0.31	0.22	1.72	1.64	5.73	3.60	5.14	1.33	10.07	9.	8.74	8.	7.01	2.18	2.	3.71
Highly Nitrogenized	3.60	3.01	0.42	0.79	0.42	8.24	8.23	26.32	1.36	4.99	0.30	6.65	7.	6.35	6.	4.70	4.63	4.	7.87
Hill and Drill Phosphate	0.67	0.77	0.42	0.53	0.33	2.73	2.47	9.26	4.46	4.94	1.72	11.12	10.	9.40	9.	7.72	2.11	2.	3.59
Pot. & Veg. Phos. revised	1.00	1.14	0.37	0.47	0.22	3.20	2.88	10.56	4.18	4.38	0.62	9.18	9.	8.56	8.	6.66	4.06	4.	6.90
Pot. and Veg. Phosphate	0.59	0.60	0.15	0.29	0.20	1.83	1.64	6.06	4.26	4.42	1.50	10.18	9.	8.68	8.	7.10	2.24	2.	3.81
Square Brand Fertilizer	0.60	0.59	0.31	0.46	0.30	2.56	2.06	7.70	3.48	4.87	1.83	10.18	9.	8.35	8.	6.92	2.26	3.	5.07
Stockbridge General Crop	1.11	1.01	0.37	0.58	0.35	3.42	3.29	11.40	4.64	3.63	2.05	10.32	9.	8.27	8.	7.07	3.78	4.	6.43
Stockbridge Cereal Man.	1.11	0.96	0.40	0.55	0.42	3.44	3.29	11.52	5.56	4.79	1.23	11.58	11.	10.35	10.	8.29	3.89	4.	6.61
Stockbridge Early Crop	2.90	1.19	0.26	0.41	0.19	4.95	4.94	15.66	4.76	3.57	0.79	9.12	8.	8.33	7.	6.63	3.09	3.	5.25
Sure Crop Phosphate	...	0.15	0.43	0.19	0.16	0.96	0.82	3.43	5.64	3.92	1.40	10.96	10.	9.56	9.	7.81	2.20	2.	3.74
J. F. Bremley																			
Corn and Potato	...	0.31	0.23	0.35	0.34	1.93	1.23	4.46	4.40	3.43	1.75	9.58	9.	7.88	8.5	6.62	2.68	2.5	4.56
Grain and Grass	...	...	...	...	...	...	...	...	8.22	1.75	0.57	10.54	10.5	9.97	10.	8.04	1.98	2.	3.37
Special Corn Fertilizer	...	0.07	0.14	0.28	0.35	0.84	0.82	...	3.68	3.85	1.15	8.68	8.	7.53	7.5	6.10	3.26	3.	5.54
Special Potato Fertilizer	...	0.28	0.11	0.23	0.23	0.85	0.82	3.04	4.36	3.07	0.61	8.04	8.	7.43	7.5	5.88	3.14	3.	5.34

†See definition, page 393.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN					PHOSPHORIC ACID							POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid	Found	Guaranteed	Valuation of potash†
Burlington Rendering Co.																			
Animal Fertilizer	...	0.98	0.26	0.61	0.37	2.22	2.	\$7.75	6.56	2.58	0.82	9.96	9.	9.14	8.	\$7.39	3.01	3.	\$5.12
Grain Fertilizer	...	0.25	0.14	0.50	0.29	1.18	1.	4.31	7.04	2.56	0.78	10.38	9.	9.60	8.	7.73	2.24	2.	3.81
Special Potato Fertilizer	0.44	0.91	0.19	0.92	0.49	2.95	2.46	10.22	4.08	5.14	1.22	10.44	9.	9.22	8.	7.35	4.08	4.	7.18
Vegetable Fertilizer	0.34	0.89	0.73	0.87	0.47	3.30	3.28	11.65	6.18	1.99	1.63	9.80	9.	8.17	8.	6.98	4.37	4.	7.43
Coe-Mortimer Co.																			
Blood, Bone and Potash*	1.39	1.24	0.74	0.70	0.32	4.39	4.1	14.70	5.00	4.94	0.92	10.86	11.	9.94	10.	7.83	3.97	4.	6.75
Blue Brand Excel. Guano	1.25	0.96	0.46	0.70	0.35	3.72	3.29	12.47	5.64	4.68	1.48	11.80	11.	10.32	10.	8.38	3.83	4.	6.51
Columbian Corn & Potato	0.28	0.28	0.44	0.23	0.18	1.41	1.23	4.94	5.26	4.87	1.53	11.66	10.	10.18	9.	8.23	2.90	2.	3.74
Excelator Potash*	1.01	1.02	0.29	0.45	0.25	3.02	2.87	9.95	4.80	3.75	1.52	10.07	9.	8.55	8.	7.08	4.02	4.	6.83
Fam. Prize Br. Grain & Gr.	...	...	...	...	...	...	...	...	7.72	3.13	1.33	12.18	11.	10.85	10.	8.90	2.12	2.	3.60
H. G. Ammo. Superphos.*	0.79	0.14	0.38	0.55	0.33	2.19	2.06	7.59	4.00	5.15	1.65	10.80	9.	9.15	8.	7.46	2.87	3.	4.88
New Englander Special†	0.21	0.21	0.03	0.23	0.18	0.86	0.82	2.95	4.80	5.60	1.17	11.57	10.	10.40	9.	8.23	2.09	2.	3.55
Prolific Crop Producer	0.32	1.10	0.36	0.69	0.35	2.82	2.47	9.69	4.16	5.05	2.02	11.93	10.	9.31	9.	7.67	2.29	2.	3.89
Special Grass Topdress.†	2.70	1.42	0.23	0.48	0.28	5.11	4.94	16.26	2.66	5.14	0.38	8.18	8.	7.90	7.	5.88	3.37	3.	5.73
Standard Potato Fert.*	1.06	1.00	0.63	0.55	0.29	3.53	3.29	11.87	4.50	3.53	2.72	10.75	9.	8.08	8.	7.16	3.82	4.	6.49
XXX Ammo. Phosphate	...	0.18	0.34	0.30	0.23	1.05	0.82	3.87	3.38	5.57	1.58	10.53	9.	8.95	8.	7.23	2.18	2.	3.71

*(Special). †(Revised). ‡(In potash column). Potash partly as sulphate. §See definition, page 393.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN					PHOSPHORIC ACID							POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid	Found	Guaranteed	Valuation of potash
Essex Fertilizer Co.																			
Comp. Grass for Topdress.	0.35	4.93	0.18	0.71	0.22	6.39	6.56	\$20.55	6.40	1.41	0.43	8.24	8.	7.81	7.	\$6.28	4.14	4.	\$7.04
Complete Corn, Gr. & Gr.	0.61	1.42	0.63	0.62	0.28	3.56	3.28	12.04	5.76	3.00	0.90	9.66	9.	8.76	8.	7.07	4.92	4.	7.17
Complete for Potatoes	0.59	1.34	0.58	0.66	0.25	3.42	3.28	11.58	6.04	2.49	1.16	9.69	9.	8.58	8.	7.03	4.17	4.	7.09
Grain, Grass and Potato	...	...	0.61	0.21	0.13	0.95	0.82	3.61	5.86	2.17	0.97	9.00	9.	8.03	8.	6.60	3.10	3.	5.27
Market Garden and Potato	0.76	0.25	0.58	0.42	0.23	2.24	2.	7.73	5.56	2.47	0.67	8.70	9.	8.03	8.	6.45	4.33	4.	7.36
XXXX Fish and Potash	...	0.93	0.73	0.33	0.22	2.21	2.	7.74	6.00	2.68	1.40	10.08	9.	8.68	8.	7.24	3.01	3.	5.12
International Agricultural Corporation.																			
Buffalo Fertilizer Works																			
Farmers' Choice	...	0.12	0.14	0.14	0.16	0.56	0.8	2.04	5.40	4.55	1.47	11.52	11.	10.05	10.	8.17	3.29	2.	5.59
Farmers' Choice	...	0.18	0.21	0.46	0.31	1.16	0.8	4.28	5.80	4.52	1.40	11.72	11.	10.32	10.	8.36	1.98	2.	3.37
Five, Eight, Four	1.69	0.89	0.47	0.55	0.40	4.00	4.1	13.23	5.64	2.56	1.56	9.76	9.	8.90	8.	6.92	4.06	4.	6.90
High Grade Manure	1.81	0.31	0.29	0.61	0.32	3.34	3.3	11.03	5.02	3.27	1.89	10.18	9.	8.39	8.	7.07	3.18	3.	5.41
New England Special	...	0.66	0.26	0.39	0.44	1.75	1.6	6.19	6.00	3.23	2.42	11.65	10.	9.23	9.	8.03	2.23	2.	3.79
One, Eight, Two	0.64	0.08	0.03	0.12	0.20	1.07	0.8	3.50	4.76	3.82	1.45	10.03	9.	8.58	8.	7.06	2.21	2.	3.76
Three, Eight, Four	0.54	0.98	0.32	0.55	0.33	2.72	2.5	9.22	5.76	3.85	1.31	10.92	9.	9.61	8.	7.83	3.79	4.	6.44
Three, Eight Four	0.42	0.84	0.26	0.64	0.33	2.49	2.5	8.53	6.04	3.48	1.98	11.50	9.	9.52	8.	8.06	3.77	4.	6.41
Topdresser	3.40	0.36	0.33	0.79	0.37	5.25	5.8	16.98	2.66	3.33	1.85	7.84	7.	5.99	6.	5.20	2.58	2.	4.56

†Potash partly as sulphate.

‡See definition, page 393.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gen†	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†
International Agricultural Corporation—Cont.																			
Buffalo Fertilizer Works—Cont.																			
Topdresser	2.75	0.83	0.29	1.54	0.48	5.89	5.8	\$9.60	4.24	2.74	1.38	8.36	7.	6.98	6.	\$5.86	1.99	2.	\$3.38
Twelve and Two	...	...	...	...	...	...	...	...	6.64	4.91	1.48	18.03	13.	11.55	12.	9.34	2.06	2.	3.50
Vegetable and Potato	1.09	0.28	0.14	0.48	0.42	2.41	2.5	8.09	4.56	3.44	2.33	10.33	9.	8.00	8.	6.99	3.18	3.	5.41
Listers' Agricultural Chemical Works.																			
Grain and Grass Fertilizer	...	...	...	...	...	...	...	...	7.52	2.52	0.56	10.60	11.	10.04	10.	8.00	2.01	2.	3.42
Revised Corn and Potato	...	0.13	0.53	0.57	0.38	1.61	1.64	6.02	4.88	3.23	1.89	10.00	9.	8.11	8.	6.92	2.07	2.	3.52
Revised H. G. Topdresser	3.77	1.07	0.36	0.46	0.28	5.94	5.76	18.81	5.32	2.86	0.86	9.04	8.	8.18	7.	6.60	3.25	3.	5.53
Revised Potato Manure	...	2.00	0.49	0.71	0.38	3.58	3.29	12.20	8.00	2.86	1.58	12.44	11.	10.86	10.	9.03	4.24	4.	7.21
Revised Vt. Corn & Potato	...	0.13	0.27	0.28	0.25	0.98	0.82	3.44	5.68	2.74	1.04	9.46	9.	8.42	8.	6.88	1.18	1.	2.01
Success Fertilizer	...	0.11	0.35	0.42	0.35	1.23	1.23	4.60	8.02	1.78	1.25	11.05	10.	9.80	9.	8.17	1.92	2.	3.26
Lowell Fertilizer Co.																			
Animal Brand, all Crops	0.42	0.79	0.53	0.41	0.26	2.41	2.46	8.27	6.56	1.95	1.22	9.78	9.	8.51	8.	7.11	3.02	3.	5.13
Bone Fert. for Corn & Gr.	...	0.87	0.57	0.22	0.15	1.81	1.64	6.27	5.88	2.61	1.04	9.53	9.	8.49	8.	6.95	2.98	3.	4.98
Cereal Fertilizer	...	...	0.63	0.25	0.14	1.02	0.82	3.88	5.48	1.92	0.82	8.32	8.	7.40	7.	6.05	1.15	1.	1.96
Corn and Vegetable	0.50	1.48	0.82	0.49	0.23	3.52	3.28	11.94	5.82	2.28	1.06	9.16	9.	8.10	8.	6.68	3.94	4.	6.70
Empress Brand	...	0.41	0.49	0.30	0.19	1.39	1.24	4.99	5.72	2.83	0.98	9.53	8.	8.55	7.	6.95	2.20	2.	3.74

†See definition, page 393.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH								
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble			Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Round	Guaranteed	Valuation of potash†	
									Reverted	Soluble	Reverted										
Lowell Fertilizer Co.—Cont.																					
Potato Manure	...	0.90	0.39	0.25	0.17	1.71	1.64	\$5.87	5.36	2.10	1.46	8.92	8.	7.46	7.	\$6.34	8.97	4.	\$6.75		
Potato Phosphate	0.45	0.74	0.29	0.72	0.35	2.55	2.46	8.81	6.32	1.89	1.23	9.44	9.	8.51	8.	6.88	4.52	4.	7.17		
Special Grass Mixture	0.96	1.92	0.45	0.64	0.29	4.26	4.1	14.07	7.20	1.54	0.56	9.80	9.	8.74	8.	7.06	4.41	4.	7.50		
Sterling Phosphate	...	0.07	0.47	0.24	0.13	0.91	0.82	3.41	5.56	2.07	1.13	8.76	9.	7.63	8.	6.35	3.36	3.	5.71		
Superior Fertilizer	0.53	1.77	0.52	0.69	0.33	3.84	3.69	12.93	7.02	1.83	0.75	9.60	9.	8.55	8.	7.20	4.39	4.	7.46		
National Fertilizer Co.																					
Ammo. Bone Phosphate	0.65	0.12	0.37	0.50	0.22	1.86	1.65	6.46	4.52	4.52	1.78	10.82	9.	9.04	8.	7.49	1.96	2.	3.37		
Special Complete Grass	1.45	0.57	0.25	1.60	0.75	4.62	4.11	16.00	3.24	5.55	1.70	10.49	10.	8.79	9.	7.16	4.79	4.	8.14		
Special Eureka Potato	1.17	0.86	0.36	0.58	0.28	3.25	2.88	10.82	3.64	4.69	1.39	9.72	9.	8.83	8.	6.75	4.33	4.	7.36		
Special Potato Phosphate	0.69	0.64	0.32	0.42	0.21	2.28	2.06	7.66	4.12	4.67	2.20	10.99	9.	8.79	8.	7.45	3.39	3.	5.76		
Tobacco Spec. Rev. (Sul.)	1.06	0.10	0.00	2.28	1.34	4.78	4.53	17.25	0.96	2.51	1.09	4.56	4.	3.47	3.	2.97	*2.98	3	5.57		
New England Fertilizer Co.																					
Complete Manure	0.60	1.43	0.70	0.53	0.28	3.54	3.28	11.97	6.96	1.75	1.00	9.71	9.	8.71	8.	7.20	4.05	4.	6.89		
Corn and Grain Fertilizer	...	0.38	0.40	0.25	0.16	1.19	1.23	4.26	4.70	2.01	1.00	7.71	8.	6.71	7.	5.57	2.12	2.	3.60		
Corn and Grain Fertilizer	...	0.41	0.40	0.29	0.13	1.23	1.23	4.39	5.44	1.30	1.08	7.82	8.	6.74	7.	5.69	2.07	2.	3.52		
Corn Phosphate	...	0.89	0.63	0.27	0.19	1.98	1.64	6.90	6.00	2.91	1.22	10.13	9.	8.91	8.	7.33	3.06	3.	5.19		
H. G. Potato Fertilizer	0.44	0.75	0.32	0.60	0.40	2.51	2.46	8.66	6.48	1.69	0.71	8.88	9.	8.17	8.	6.64	4.12	4.	7.00		

*Potash largely if not entirely as sulphate. †See definition, page 393.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro-Gen [†]	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phosphoric acid [†]	Found	Guaranteed	Valuation of potash [†]
New England Fertilizer Co.—Cont.																			
Peerless Fertilizer	...	0.07	0.55	0.21	0.14	0.97	0.82	\$3.64	5.56	1.73	0.75	8.04	8.	7.29	7.	\$5.96	1.15	1.	\$1.96
Potato Fertilizer	...	0.81	0.45	0.24	0.15	1.65	1.64	5.70	5.60	1.40	0.82	7.92	8.	7.00	7.	5.79	3.95	4.	6.72
Superphosphate, all Crops	0.40	0.86	0.69	0.46	0.31	2.72	2.46	9.42	6.82	2.45	1.18	10.45	9.	9.27	8.	7.65	3.26	3.	5.54
Parmenter & Polsey Fertilizer Co.																			
Corn and Grain Fertilizer	...	...	0.61	0.24	0.15	1.00	0.82	3.80	6.42	1.79	0.85	9.06	9.	8.21	8.	6.73	3.54	3.	6.02
Plymouth Rock Brand	0.40	0.88	0.62	0.46	0.24	2.60	2.46	8.95	7.84	1.00	1.17	10.01	9.	8.84	8.	7.44	3.14	3.	5.34
Potato Fertilizer	...	0.87	0.57	0.27	0.15	1.86	1.64	6.46	5.78	2.05	1.13	8.96	9.	7.88	8.	6.51	3.05	3.	5.19
Reading Bone Fertilizer Co.																			
Alkaline Phos. and Potash	...	...	...	...	...	...	...	...	5.60	3.68	0.94	10.22	11.	9.28	9.	7.44	1.92	2.	3.26
All Crop Special	...	0.86	0.31	0.30	0.18	1.65	1.64	5.67	4.62	3.49	0.89	9.00	8.	8.11	7.	6.50	3.79	4.	6.44
Farmers' Tankage & Pot.	...	0.07	0.12	0.45	0.22	0.86	0.82	3.22	5.40	3.80	1.00	10.20	9.	9.20	8.	7.38	3.08	3.	5.15
Gilt Edge Potato & Tob.	...	1.22	0.32	0.13	0.12	1.79	1.64	5.95	8.84	4.06	1.30	14.90	13.	12.90	12.	10.43	3.93	4.	6.68
Never Fail Crop Grower	...	0.53	0.22	0.16	0.09	1.00	0.82	3.43	5.18	3.80	0.60	9.58	9.	8.98	8.	7.04	0.86	1.	1.46
Prize Winner	...	1.28	0.49	0.45	0.18	2.40	2.46	8.23	6.98	3.50	1.17	11.65	10.	10.48	9.	8.50	3.70	4.	6.29
Special Grain and Grass	...	0.07	0.23	0.40	0.18	0.88	0.82	3.30	4.98	2.17	1.00	8.15	8.	7.15	7.	5.90	3.40	3.	5.78
Potato and Tobacco Man.	0.20	0.07	0.19	0.40	0.16	1.02	0.82	3.66	4.00	2.76	0.74	7.50	7.	6.76	6.	5.43	4.26	4.	7.24
Truck, Fruit, etc., etc.	...	1.87	0.51	0.67	0.30	3.35	3.29	11.42	5.28	3.77	1.73	10.78	9.	9.05	8.	7.55	3.62	4.	6.15

†See definition, page 393.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN							PHOSPHORIC ACID							POTASH				
	In nitrates	In ammonia salts	Water soluble organic	Active water insoluble organic	Inactive water insoluble organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Total guaranteed	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†
Rogers & Hubbard Co.																			
All Soils—All Crops	2.51	0.07	0.51	0.29	0.24	3.62	3.3	\$11.70	3.76	3.32	1.94	9.02	9.	7.08	8.	\$6.11	2.69	2.5	\$4.57
Complete Phosphate	0.41	0.10	0.36	0.36	0.24	1.47	1.5	5.19	1.14	5.65	2.18	8.97	8.	6.79	7.	5.74	1.16	1.66	1.97
Complete Phosphate	0.44	0.09	0.37	0.37	0.24	1.51	1.5	5.32	1.54	4.56	2.86	8.96	8.	6.10	7.	5.56	1.39	1.66	2.36
Fert. Oats and Topdress.	8.17	...	0.15	0.13	0.10	8.55	8.5	25.95	...	5.29	3.10	8.39	8.	5.29	4.5	4.94	3.94	4.	6.70
Fert. Seed Down and Fruit	0.22	0.13	0.32	0.91	0.72	2.30	2.2	8.47	0.20	8.04	8.87	17.11	16.	8.24	6.5	9.34	4.43	4.	7.53
Potato Phosphate	0.79	0.07	0.47	0.57	0.34	2.24	2.	7.82	1.40	7.05	3.50	11.95	10.	8.45	9.	7.46	2.31	2.25	3.93
Sol. Corn and Gen'l Crops	1.55	0.10	0.24	0.52	0.31	2.72	2.5	9.03	1.80	4.43	2.69	8.92	8.	6.23	6.	5.62	3.24	3.	5.51
Soluble Potato Manure	3.23	0.14	0.45	0.95	0.53	5.30	5.	17.45	0.52	6.20	4.02	10.74	10.	6.72	7.	6.37	12.17	2.	3.90
Soluble Tobacco Manure	2.89	0.11	0.00	1.31	0.71	5.02	5.	16.69	1.32	6.43	3.85	11.60	10.	7.75	7.	7.10	3.25	3.33	6.03
F. S. Royster Guano Co.																			
Favorite Compound	...	0.95	0.47	0.19	0.13	1.74	1.65	5.94	6.68	3.99	1.50	12.17	10.5	10.67	10.	8.73	2.12	2.	3.60
Parfait	0.12	2.22	0.97	0.78	0.31	4.40	4.11	15.07	4.28	3.39	3.41	11.08	8.5	7.67	8.	7.15	3.89	4.	6.61
Truckers' Delight	...	1.81	0.47	0.74	0.35	3.27	3.29	11.54	4.50	3.94	1.56	10.00	8.5	8.44	8.	6.98	4.33	4.	7.19
Utopia Compound	...	1.42	0.48	0.44	0.23	2.57	2.47	8.77	4.50	4.01	1.36	9.37	8.5	8.51	8.	6.95	3.21	3.	5.46
Wheat, Oats and Barley	...	0.41	0.06	0.29	0.17	0.96	0.82	3.25	4.24	3.98	1.38	9.60	8.5	8.32	8.	6.73	1.99	2.	3.38

*Potash largely if not entirely as sulphate. †Potash partly as sulphate. ‡See definition, page 393.

ANALYSES OF LICENSED FERTILIZERS

BRAND	NITROGEN						PHOSPHORIC ACID						POTASH						
	In nitrates	In ammonia salts	Water soluble organic	Active water organic	Inactive water organic	Total found	Total guaranteed	Valuation of nitro- gent	Soluble	Reverted	Insoluble	Total found	Available found	Available guaranteed	Valuation of phos- phoric acid†	Found	Guaranteed	Valuation of potash†	
J. W. Sanborn.																			
For Grass and Grain	1.86	2.26	0.56	0.24	0.22	5.14	4.94	\$16.47	6.84	1.83	1.13	9.80	9.	8.67	8.	\$7.20	8.39	3.	\$5.76
For Hill and Drill	...	1.41	0.58	0.28	0.30	2.57	2.47	8.78	6.28	2.46	1.17	9.91	9.	8.74	8.	7.21	8.38	3.	5.75
For Potatoes and Corn	...	2.43	0.43	0.38	0.27	3.51	3.29	11.63	6.22	2.81	1.10	10.13	9.	9.08	8.	7.39	8.78	4.	6.43
Sanderson Fertilizer & Chemical Co.																			
Atl. Bone, Fish, Potash	...	0.22	0.41	0.70	0.72	2.05	1.64	7.63	2.32	6.52	1.31	10.25	9.	8.94	8.	7.01	1.91	2.	3.25
Corn Superphosphate	...	0.16	0.68	0.53	0.47	1.84	1.64	6.88	3.08	5.77	1.35	10.20	9.	8.85	8.	7.04	2.06	2.	3.50
Potato Manure*	0.43	0.90	0.07	0.30	0.33	2.08	2.06	6.74	4.60	4.57	0.56	9.78	9.	9.17	8.	7.10	3.06	3.	5.20
Special with Potash*	0.82	1.48	0.10	0.31	0.29	3.00	2.88	9.71	6.20	3.37	0.65	10.32	9.	9.57	8.	7.58	4.44	4.	7.55
Virginia-Carolina Chemical Co.																			
Ammo. Potash Comp.	...	0.39	0.30	0.12	0.16	0.97	0.82	3.41	6.24	2.64	1.18	10.06	9.	8.88	8.	7.31	2.42	2.	4.11
Little Giant Fert.	...	...	...	...	...	...	...	...	5.84	4.66	1.26	11.76	10.	10.50	9.	8.43	2.96	2.	5.03
Owl Potato, Truck	...	0.87	0.37	0.35	0.34	1.96	1.65	6.73	6.64	2.72	1.48	10.84	9.	9.36	8.	7.80	3.59	4.	6.10
Special Corn and Grain	...	1.36	0.41	0.15	0.13	2.05	1.65	6.84	6.88	3.72	1.40	12.00	11.	10.60	10.	8.66	3.80	3.	5.61
Star Potato, Vegetable	...	2.26	0.67	0.44	0.35	3.72	3.29	12.56	3.68	2.44	1.51	7.68	7.	6.12	6.	5.25	4.28	4.	7.28
Universal Fertilizer	...	0.18	0.38	0.16	0.28	1.00	0.82	3.68	4.30	4.80	1.34	10.44	10.	9.10	9.	7.34	3.54	3.	6.02
XXX Fish and Potash	0.26	0.30	0.62	0.39	0.47	2.04	1.65	7.33	3.52	4.12	1.00	8.64	9.	7.64	8.	6.10	2.46	2.	4.18

* (Special). †See definition, page 393.

VI. CROP ROTATION

By R. T. BURDICK

DEFINITION

The practice of crop rotation involves growing a succession of different crops on the same field, thus varying from the single crop system, which contemplates the continuation of the same crop on a field. If the crops in the rotation always are grown in a fixed order the method is called a "definite" rotation. When the number of years required for the complete rotation is constant, the rotation is "fixed." Thus there may be a definite fixed rotation, which has advantages to be discussed later; or there may be a very indefinite, unstable rotation, which, nevertheless, gives a change of crops. Land left in grass until weeds prevail, plowed two years, then returned to grass, is an example of the latter method. A rotation of one year each of corn, oats, clover, corn, etc., would be an example of the former method. Parker (1) says that "The term 'crop rotation' is used to define a system of growing grain, grass and cultivated crops on a given area of land in such order and succession as to keep the soil productive in good tilth, free from weeds, in such mechanical condition that moisture for the crops is easily controlled, and so as to insure the productive employment of the farm proprietor's capital and labor." This is the attitude which is necessary to fit the growing of crops into any scheme designed for the building of a permanent agriculture.

HISTORY

Crop rotation has been practiced in some form since the early days of agriculture. One of the first farm practices closely related to rotation was the use of the bare fallow, in which the land was left free of crops for one year, and the soil stirred occasionally. The main advantage derived from this practice was that the soil was thus loosened and the decomposition of its organic matter hastened.

Modern study has shown that little can be gained to offset the loss of a year's crop. A cultivated crop, such as corn, insured the beneficial stirring of the soil, and at the same time utilized the plant food, which under the fallow system, was quite largely lost by leaching.

The increase in the yield of all crops grown after clover, alfalfa, or peas, as early as one hundred years before Christ, led agricultural writers to advocate growing these crops occasionally on each field. In 1790, George Washington found in use on Long Island a rotation of

corn, manured one year, oats one year, wheat one year, and seeded to clover and timothy meadow one year, and pasture one year (1). This is almost the identical rotation used today in the northeastern states where wheat is grown.

More is known today than was known in Washington's time concerning the requirements and limits of crop growth and the reasons for the results secured from growing specific crops, such as clovers. With this knowledge we are able today to build a permanent type of agriculture under widely varying conditions. It is significant, however, that much of our science merely places a foundation of reason under the successful practice worked out in the past by observing farmers.

REASONS FOR CROP ROTATION

There are many benefits, both direct and indirect, to be obtained from a definite rotation of crops. In order to emphasize them, they will be taken up in some detail.

1. *Weed control.* If one crop is grown continuously on a field certain weeds will tend to increase until they become a very serious pest. With each crop appear certain typical weeds which are much less serious in other crops. The principal weeds that appear with corn and other intertilled crops in this section are redroot, pigweed or lamb's quarters and foxtail—sometimes called pigeon grass. With barley, oats and grain crops the most persistent weeds are wild mustard and kale, although the ragweed, the thistle and other weeds may abound. The grasses have as their enemies daisies, wild carrots and paintbrush. These weeds succeed because their life cycle fits in with the crop grown. Pigweed and redroot seldom are found in hay or grain. Mustard, daisies and paintbrush do not grow in cultivated crops. A change of crops practically eliminates, or at least subdues, the weeds.

Nature is said to abhor a vacuum. It seems to dislike soil vacuity. If man fails to clothe a soil, nature does it, using weeds as clothing. In few instances is the weed better able to endure than is some crop that is of value. It is only when a crop continues too long in a field, or is neglected while there, that nature fills the gap with weeds. By changing crops every year or two it is possible continually to keep ahead of the weeds.

2. *Insect control.* Many insects trouble only one plant, while other insects are more cosmopolitan in their tastes. The clover root borer infests only the clover. The June bug larvae, or "white grub" chiefly affects sod, although it lives over one year in tilled land, and

causes much damage. Its eggs never are laid in tilled ground and seldom in ground newly seeded.

Changing crops is an effective method of checking the damage from insects. Sometimes it is necessary to omit the crop entirely for a few years. It is interesting in this connection to note that the widespread prevalence of the Hessian fly practically drove the wheat growing industry from Vermont, whereas economic changes have aided in preventing this crop from being cultivated on a large scale.

3. *Plant disease control.* When a plant disease like potato scab becomes troublesome it is possible to check it by changing the crop for a few years. Crop rotation is not a cure for plant disease, but it is a check to such diseases because it reduces the length of time during which the crop remains on one field. Some diseases, such as club-root of cabbage, will vanish if the crop is not grown on the soil for several years.

In many instances the prevalence of weeds, insects and plant diseases has forced farmers to adopt the practice of crop rotation, by making it unprofitable for them to continue with a single crop. Doubtless they will cause similar crop changes in the future.

4. *Labor saving.* Crop rotation often makes it possible to grow two crops with one preparation, or after one plowing. In this state the practice of seeding grass in grain is the best example. In western New York, wheat is seeded after beans simply by discing the soil, while in the Middle West, oats are put on disced corn stubble. The saving in power and time made possible by eliminating one plowing or one season's harrowing, increases the area which one man can handle and at the same time reducing the cost of putting in an acre of crops.

5. *Occupation of the land.* Long ago it was believed that if land lay fallow for a season it would become more productive. Now it is known that thorough cultivation of an intertilled crop, such as corn, potatoes or beans, does the soil as much good as the fallow and furnishes an additional crop. Vermont's rainfall is sufficiently heavy so that the plant food which becomes available by the processes of decomposition of soil and organic matter will leach away unless utilized by the plants in their growth. It follows that some system of cropping which will keep the ground covered, will conserve more fertility than it is possible to secure when the soil lies bare to the weather. This is one of the strongest arguments in favor of the use of catch and cover crops following corn, or in tilled orchards.

6. *The maintenance of the humus supply.* An adequate humus

or organic matter content is one of the essentials of a fertile soil. It is in a continual state of decay and loss by natural decomposition on the one hand, and in a continual state of renewal by plant residues on the other hand. The growth and removal of certain crops, such as corn, potatoes and all grains, cause greater loss of humus than gain in the shape of stubble. On the other hand grasses and clovers leave stubble or sod that more than balance the loss through decomposition. A proper balance of the humus-destroying crops with grass and clover will maintain the soil in proper condition.

7. *The maintenance of the soil nitrogen supply.* Clovers and legumes generally not only make humus but help to maintain the nitrogen supply of the soil. No single cropping system can maintain supplies either of humus or of nitrogen, unless legume cover crops are alternated with other crops. This is not as economical as a plan that provides a harvested legume crop and leaves the stubble to be plowed under.

8. *Crop alternation.* Rotation provides an alternation of deep and shallow-rooted crops. Corn and clover are deep-rooted plants and draw their nourishment from both the upper and the lower soil. Potatoes, small grains, and grasses are shallow-rooted plants and a rotation of these crops tends to utilize the soil to the maximum depth.

9. *Regulation of plant food usage.* Crop rotation tends to favor a balanced removal of plant food. Corn uses large amounts of nitrogen, potatoes consume relatively more potash, while clover requires large amounts of nitrogen, potash and lime. Grain crops require plant food that is readily available, while corn utilizes less soluble plant food. A proper rotation of these plants apparently would tend to remove first one, then another plant food in excess, and so serve to keep the removal balanced. If one crop was "hard" on the soil, another crop would give it a chance to recuperate. While there is some truth in the idea, it must be remembered that larger crop yields result because of the proper balance of other factors. The final outcome is a greater total removal of each plant food.

10. *Soil health.* Rotation may serve in some degree to control the formation of toxic substances. When a crop has been grown continuously on a field the yield becomes much reduced, or may fail altogether. This may be due to one or to many of the causes enumerated above, or it may be due, as some claim, to the fact that the accumulated plant residues of a crop tend to check the proper growth of that particular crop. The validity of this claim is not as yet acknowledged by

all students of soil problems. However, whether true or false this much surely is true, that if crop rotation is practiced the difficulty will be overcome.

11. *Soil aeration.* Rotation keeps the soil in good physical condition. This is accomplished largely by the maintenance of the humus supply and by the tendency of certain crops, such as grass, to improve the tilth of the soil.

12. *Manurial utilization.* Crop rotation provides a satisfactory means of utilizing farm manures and fertilizers. All crops respond to farm manure, but some do so more readily than others. Shallow-rooted crops respond more readily to the use of commercial fertilizer if other soil factors favor. The growth of clover and grass makes possible the keeping of more livestock to furnish manure. By rotation, then, it is possible to furnish manure, and then so to use it that it will do the most good.

13. *Increased crop yields.* If no better yield resulted from the practice of rotation, still it would be of value as a means of reducing the cost of production. But as a matter of fact rotation increases total crop yields.

The relation between crop rotation and crop yields has been studied at many American experiment stations. A few of the typical results follow:

The Minnesota station in bulletin 125 (1913) summarized many years of trials made on an extensive scale. Thus the results of nine years of trials, beginning a few years after the work started and closing eight years ago, stated in average acre yields for the nine years, were as follows:

	Corn, bushels	Wheat, bushels	Hay, tons
Continuous growth, unmanured.....	22.9 ¹	18.5	..
3-year rotation (corn, wheat, clover), unmanured	48.1	21.	2.9
5-year rotation (corn, wheat, meadow) 8 tons manure applied every fifth year	56.7	25.9	3.8 ²

¹Eight years; record lost for one year.

²Seven years.

In the same bulletin are shown cuts which clearly set forth the situation and which, through the courtesy of the Minnesota station, the writer is permitted to include in the present bulletin. The reader's careful attention is directed to these plates, to the accompanying statements underneath them and to the lessons they teach.

The Ohio station in circular 131 (1913) reports concerning 19 years of field trials, 1894-1912, made on the home (Wooster) farm, in terms of acre yields. The comparisons chosen from the many results attained and displayed in the three tables following exhibit yields under rotation with those secured on continuous growth.

UNFERTILIZED AREAS

	Corn		Wheat		Oats		Hay Tons
	Bushels grain	Pounds stover	Bushels grain	Pounds stover	Bushels grain	Pounds stover	
Continuous	15.9	1,245	7.5	938	22.9	921	...
3-year rotation..	34.4	2,169	10.6	1,310	...	....	1.35
5-year rotation..	29.7	1,668	10.2	1,045	31.	1,300	1.13

When manure was applied once during the rotation, that is to say at 3- or at 5-year intervals, either alone or, in the 3-year rotation, fortified with acid phosphate or with floats, marked results were attained.

IN THE 3-YEAR ROTATION (CORN, WHEAT, CLOVER)

	Corn (15 crops)		Wheat (15 crops)		Clover (12 crops)	
	Bushels grain	Pounds stover	Bushels grain	Pounds straw	Tons	
Unfertilized	34.4	2,169	10.6	1,310	1.35	
8 tons manure.....	59.5	3,358	20.7	2,368	2.07	
8 tons manure + 320 pounds acid phos- phate	66.1	3,581	25.5	2,837	2.54	
8 tons manure + 320 pounds floats ..	65.4	3,680	25.4	2,791	2.51	

IN THE 5-YEAR ROTATION (CORN, OATS, WHEAT, CLOVER, TIMOTHY)

	Corn		Oats		Wheat		Hay Tons
	Bushels grain	Pounds stover	Bushels grain	Pounds stover	Bushels grain	Pounds straw	
Unfertilized	29.7	1,668	31.	1,300	10.2	1,045	1.13
16 tons manure..	49.	2,460	42.9	2,022	21.7	2,345	1.99
8 tons manure..	43.7	2,178	37.8	1,673	17.7	1,878	1.62

The Illinois station in bulletin 125 (1908) compares continuous corn cropping with an alternation of corn and oats and a corn, oats, clover 3-year rotation. Two comparisons are made of trials under way respectively 13 and 29 years, the statement being made on the basis of acre yields for the last three years during which each area was planted to corn.

Crop system	Crop years	Bushels (13 years)	Bushels (29 years)
Continuous corn	1905, 1906, 1907	35	27
Corn and oats	1903, 1905, 1907	62	46
Corn, oats, clover.....	1901, 1904, 1907	66	58

The Illinois investigator, commenting on these results says that

"the lesson of these experiments is that 12 years of continuous cropping when corn followed corn reduces the yield from more than 70 bushels per acre (the yield at time that experiment began) to 35 bushels after which the decrease is much less rapid, dropping 8 bushels in 16 years to an average of 27 bushels at the end of the 29-year experiment" (7).

Where corn and oats are grown the decrease is less rapid than with either alone. Where corn, oats and clover are grown the yields of corn dropped from over 70 bushels to 66 bushels in the 13-year experiment and to 58 bushels in the 29-year experiment. "In this system the most marked reduction in crop yields has not yet appeared, although it must be expected in the future, because the clover crop is already beginning to fail on the oldest fields, even in seasons when clover succeeds on newer land under the same relations" (7).

In further experiments the Illinois station found that whenever crop residues of straw, corn stalks and stubble were used alone together with lime or with lime and phosphoric acid, the yield of corn in the corn, oats, clover rotation was not only maintained but actually increased to 90 bushels when lime and phosphoric acid were used. Furthermore, whenever in place of crop residues their equivalent in farm manure was used, the yields were increased in all instances.

AVERAGE YIELDS OF THREE CORN CROPS IN CORN, OATS, CLOVER ROTATION.—
ILLINOIS 13-YEAR EXPERIMENT

Crop year	Treatment	Grain farming ¹	Livestock farming ²
1905-6-7	None	67 bushels	81 bushels
1905-6-7	1,000 lbs. lime, applied in 1902	72 bushels	85 bushels
1905-6-7	1,000 pounds lime, applied in 1902 and 200 pounds steamed bone meal applied annually..	90 bushels	93 bushels
1905-6-7	Lime and bone as above and 100 pounds sulphate of potash annually	94 bushels	96 bushels

¹Legume catch crops and all crop residues except grain and seed plowed under.

²Manure applied in proportion to previous crop yield and all of plant but stubble removed.

At the Indiana station, the results of a 20-year period of experimentation with rotation and with fertilizers as set forth in circular 25 (1911) show:

1. That a rapid decrease followed continuous grain culture;
2. That yields were maintained for a longer period when recourse was had to a rotation including legumes and grass;
3. That an actual increase in productivity occurred in the twentieth year as compared with the first on areas which have been fer-



FIGURE 1.—Corn grown continuously for 18 years. The average yield during the last 10 years of the 18-year period was *27.5 bushels per acre*. Compare with picture shown below.



FIGURE 2.—Corn grown in a 5-year rotation of corn, wheat, clover and timothy meadow, pasture and oats, on which 8 tons of manure were applied once in 5 years. The average yield during the last 10 years of an 18-year period was *61.3 bushels per acre*. Compare with picture shown above.

NOTE.—Figures 1 to 8 are supplied through the courtesy of the Minnesota Experiment Station. They were used in a joint publication of the Bureau of Plant Industry, United States Department of Agriculture, bulletin 236 (1913), and that station, bulletin 125 (1913). The courtesy of the Minnesota station is gratefully acknowledged.



FIGURE 3.—Shovelful of soil taken from plot on which corn growth continued for 18 years, produced on the average during the last 10 years of the 18-year period *27.5 bushels per acre*, as displayed in figure 1. Note its compact, non-friable nature. Compare with the dark, humus-containing, friable soil shown below.



FIGURE 4.—Shovelful of soil taken from plot on which corn, grown in 5-year rotation (corn, wheat, clover and timothy meadow, pasture and oats), manured once in 5 years, produced on the average during the last 10 years of an 18-year period, *61.3 bushels per acre*, as displayed in figure 2. Note its dark tint, an evidence of an ample humus supply, its friable character and its plant debris. Compare with the dense, compact, non-friable soil shown above.



FIGURE 5.—Vertical section of soil on which corn has grown continuously for 18 years. Note the light color of the surface soil, indicative of lack of humus, and the relative lack of deep roots. Compare and contrast with picture shown below and with that shown on the top of the next page, noting differences in depth, color, friability, rooting habits, amount of stubble likely to be left at harvest, etc.



FIGURE 6.—Vertical section of soil on which fodder corn is growing on a newly broken alfalfa sod. Note the dark hue, indicative of plentiful humus supplies, the abundant and deep rooting of the new crop. Compare and contrast with picture shown above, noting differences in depth, color, friability, rooting habits, amount of stubble likely to be left at harvest, etc.



FIGURE 7.—Vertical section of soil near a corn plant growing on a newly broken alfalfa sod. Note the dark hue, indicative of plentiful humus supplies, the abundant and deep rooting of the new crop. Compare and contrast with the upper figure on the last page (Fig. 5) noting differences in depth, color, friability, rooting habits, amount of stubble likely to be left at harvest, etc.



FIGURE 8.—Timothy sod backset after producing a flax crop.

tilized and also have grown clover, a result which was not attained when grain only was grown.

Ought American farmers to ask for further proof of the soundness of the advice which stresses the use of crop rotation and of manure in order to maintain crop yields at a maximum?

OBJECTIONS TO A FIXED ROTATION

It is well to study the objections which are raised by farmers against the practice of crop rotation in order, if possible, to obviate these difficulties and to the end that a system of cropping may be developed which shall meet farm needs.

1. There is no desire to plan for a definite area of a crop. It is considered advisable to vary the acreage each year as prices vary, determining each year's acreage upon the basis of the price of the previous year; or the crop is of doubtful value and hence is tried in varying amounts. This latter practice is directly opposed to the policy of shrewd farmers, who refuse to grow a crop if it is of doubtful value, while if it is profitable they grow it each year.

2. Accidents break up the rotation. For example, a poor season prevents one from preparing the land, or a seeding fails.

3. Fields are not of the right size to permit the growing of uniform areas of crops.

4. The soil is not of uniform quality, is ill-drained, or there is lack of fertilizer, lime or manure.

It appears according to Holmes (9) that there are many reasons advanced why crop rotation is not more generally practiced throughout the country. The answers of thousands of correspondents of the Federal Department of Agriculture to the question, "Why do not farmers more generally rotate their crops?" are epitomized in the language of the author of the article in question as follows:

"(1) New land; (2) old land still regarded as inexhaustible; (3) reliance upon commercial fertilizer for land without humus; (4) the credit system in the South; (5) the poverty of the farmer, preventing an advancement of soil enrichers; (6) tenancy, with the features of short term, absent landlord, credit, poverty, indifference, and incapable tenant; (7) special inducement to raise one money crop, as corn near distilleries in Kentucky and Ohio, hay near lumber camps in Michigan; (8) the limitations of the semi-arid region; (9) contempt for 'book farming,' and preference for grandfather's 'rule o' thumb'; (10) keeping a small number of live stock; (11) when the soil is sick with over-

cropping, the farmer is not well enough informed to know the nature and cause of the malady; (12) the farmer is in a rut, lacks initiative, and needs help to get out; (13) the cash and cotton rents are so high that the tenant can not get a start in rotation."

Some of these reasons do not operate in Vermont, and some have been largely overcome; and, yet with the objections given above, they represent the forces which prevent farmers from securing the full advantage of crop rotation.

ADVANTAGES DERIVED FROM A FIXED ROTATION

1. *It systematizes farming.* The fixed rotation allots a definite area to each crop each year. When a farmer knows just how many acres of each crop he will have he can plan his work systematically. He can determine the amount of seed and fertilizer needed, estimate the help required, make a rough approximation of his probable income, and put his entire business on a definite basis. With this system established, he can devote his thought to cost of production, marketing, and labor distribution problems, all of which can be solved best under definite systems of cropping.

2. *Some definite area of a crop is best for a farm.* The climate, markets, soil, topography, type of farming and related factors will determine the crops which a farm will grow. Once that is established, it should be possible to decide upon the proper area of each crop selected. If the crops are grown for feed, the stock will require as much per head one year as another. A favorable season may give more feed than is needed and a dry year may produce much less feed than the amount required, but year in and year out the area needed to furnish silage or hay per animal varies but little from the average. This area once determined should be thus used until a change in the type of farming or an improvement in methods of production suggest reasons for a change. The same thing is true of crops grown for sale. The area of these crops should be planned to afford a proper labor distribution with the labor required on feed crops. If extra labor is available these crops also should be planned with a purpose to secure the greatest possible use and income from the area available, over a period of years.

REQUIREMENTS OF A GOOD ROTATION

Some of the essentials of a successful rotation already have been stated. It will be well to summarize them and to give others in some detail.

1. *The area* of each crop should be nearly the same each year unless there is some definite reason for changing it.

2. *The system* adopted should provide pasture and roughage for all stock kept. There may be a question as to the desirability of growing all the grain required for the stock, especially if there is a good cash crop market. There is no question but that all the roughage should be grown for home needs. Hay and silage are bulky for their value. The cost of bringing them to the farm, added to their market price, puts the farmer at considerable disadvantage in producing stock products at a profit. Whether the feed to be supplied in summer shall be obtained in part or wholly from the pasture or whether roughage shall be grown to supplement or replace pasture is a question best settled by the individual farmer. The type of soil, its topography, the likelihood of drought, of insect pest ravages, the nature, nearness, size, etc. of the market for stock products—all should be considered before making a final decision. Whatever the choice, an area should be provided that will furnish feed in a poor year. The excess can be disposed of in a good year more easily than the shortage can be purchased at a loss in a poor year.

3. *One tilled crop* at least should be grown. The productive power of the soil is improved by the stirring of the cultivator, and the crop that follows gives a better yield. Crop cultivation checks weeds. Each field on the farm, if possible, should be thus cultivated in regular rotation. If the land is too low and too wet for cultivated crops, the hay crop will be improved if the field is plowed occasionally in mid-summer and reseeded. The new turf will repay the labor, and the weeds will be checked.

4. *One sod crop*—a legume if possible—should be grown and two are better than one. An unbroken series of tilled crops or of grain crops is disastrous to the soil. (See pp. 444-446 and accompanying plates). If a grass or a legume crop is interjected, a change is introduced, and the shallow, abundant grass roots put the soil in fine tilth. It is difficult, if not impossible, to keep the soil in best condition without returning it to sod at intervals. Abundant use of cover crops are a substitute for sod, but are not practical except under intensive conditions.

5. *Humus maintenance* should be secured. Grass, clover, and cover crops are humus-supplying crops; and farm manure is serviceable to this end.

6. *The most profitable crop, the money crop*, should occupy as

large an area as possible. It is usually advisable to devote half of the tillable area to the crop best adapted to the region. In Vermont, hay is almost always the most profitable crop. Although corn, potatoes and oats give large yields here, very rarely will it be advisable to allot to any one of these crops more than one-third, or, better, one-fourth of the tillable area.

The farmer should choose for each season of the year a crop that will pay best for that season, rather than devote his entire farm to one crop, demanding work at only one season. For example—oats, corn, potatoes and hay do not seriously conflict with each other, with the exception of cultivation and early haying. A farm given over entirely to hay would demand much labor for July and none either before or after that time, except for marketing. A dairy farm growing 15 or 20 acres of corn should have as much hay as the men and horses can harvest, if labor is to be utilized to the best advantage.

7. *Crop concentration* is important. The area of one crop should be in as few fields as possible. In rearranging a farm for a fixed rotation it is seldom possible to secure fields of equal areas. Gullies or ledges will form impassable boundaries. A crop must be grown in more than one field to give the required acreage. In planning the readjustment of fields and crop acreages this point should have attention. The system should be made as simple as possible and the acreage varied, if necessary, one or two acres from the norm. It were unwise in order exactly to fill out an estimated area to sow an acre patch in a separate field. (See page 456 for problem in readjusting fields of unequal size).

8. *The cost of changing from one crop to another* should be borne in mind in deciding upon the number of years required for the complete cycle of crops in the rotation. For example, the cost of grass and clover seed is expressed conveniently as a rate per acre for seeding. If the acreage of crops which is required on the farm can be secured as readily by employing a 5-year rotation in lieu of a 4- or a 3-year rotation, and if the crops succeeded under these conditions, a considerable yearly saving of grass seed will be made, for only one-fifth of the entire area must be seeded yearly instead of a third or a fourth. If 45 acres are rotated, 9 acres instead of 15 or $11\frac{1}{4}$ acres would be seeded, a yearly saving of seed which would be well worth while. However, this is a minor point. The crop yield and the proper area of each crop are the essential things to be secured. The cost of seed is a small price to pay for these things.

9. *The fields should not be plowed too long* before they are ready for use, for the humus formed by the sod growth is lost rapidly under cultivation. Manure, cover crops or sod must be used to replace the loss. It is seldom best to allow more than three years between sod and sod and two years are better where the soil is light.

Van Slyke (10) states that in every rotation there should be one crop to sell, one clover or other legume crop for collecting nitrogen, one forage crop and one cultivated crop. Potatoes satisfy the first and last requirement, clover the second and third, and corn the third and fourth. He further adds that climate, soil, type of farming, and commercial pests must be considered in determining the type of rotation.

HOW TO TELL THE MERITS OF DIFFERENT ORDERS OF GROWING CROPS

Having selected the crops to be grown, the order in which they are to be grown is important. For example, it must be determined whether corn, or oats, shall be planted on sod; whether grass shall follow oats or corn. Two tests should be applied; the *labor required* and the *yields secured*. The most profitable crop should be given the best place in the rotation. The farmer should know how the labor required for plowing, preparing land and seeding compares with the different orders of crops. Oats are sometimes grown on lighter soils following corn or potatoes, when the preparation of the seed bed is done by discing without plowing. The question naturally arises, can corn follow oats simply by discing the oat stubble?

Usually oats do not yield as well following sod as following corn. With proper applications of manure there will be little difference in the yield of corn and oats after sod. Nature made corn a gross feeder when she provided it with a well developed and deep root system; and it can utilize sod and manure to better advantage than can any of the small grains.

Shall corn or potatoes follow sod? Both yield well. If the sod is of several years standing, it is quite likely to be filled with white grubs. These insects will damage corn less than potatoes and few will remain the second year. For this reason a better quality crop will be secured if potatoes follow corn. If the sod is clover and not over two years old, few grubs will be present. The potatoes do well on the clover sod and the decomposing turf checks the scab fungus. Corn also will thrive on this sod. If potatoes are a profitable crop they should be thus favored and followed by corn.

The question of seeding also is important. Do grass and clover make the best stand following corn, oats, barley or potatoes? How does the cost of putting in the seed compare, following these crops? Is a grain nurse crop needed for the grass? These are the questions that practice can best answer in a given community. It is known that barley is a better nurse crop than oats, because it shades the ground less and uses less soil moisture. It is known that on well drained soils summer seeding following the last cultivation of corn gives good stands of grass. Oats, however, may be desired on the farm, and seeding then probably will be done at least expense in the oats, unless barley is grown following oats.

The application of commercial fertilizer and farm manure should be made in accordance with what is considered the best crop. Corn and grass can secure the most returns from direct application of manure. Grains and potatoes often do best the second year after manure has been applied, because the organic matter of the manure must be well decomposed before they can utilize it advantageously. The fact that the grains and potatoes are shallow-rooted crops and so called weak feeders, explains why they respond so readily to the application of available commercial fertilizers when the soil otherwise is in good condition.

COMMON EXAMPLES OF ROTATION

Corn, potatoes, oats, hay, with some barley, wheat and rye are Vermont's important crops. Heavy soils are kept in grass as long as fair yields are returned—and sometimes considerably longer. Long rotations are the common practice. On light soils hay does not endure more than two or three years and hence shorter rotations are the rule among successful farmers.

Corn, almost universally, is placed on sod. Sometimes it is grown for two years in the same field, which is then seeded; or corn is followed by oats, and the land is seeded. Occasionally oats are put on sod and the field is seeded, or followed by barley and the land is seeded. Sometimes sod is plowed and reseeded without any other crop.

Potatoes are confined to the loams and light soils. In small home gardens they are grown on the same land continuously, or with occasional shifts to other crops, the humus content being maintained by manure. Commercially, the common practice is to put potatoes in a definite rotation with clover and a small grain.

As a result of these various practices the following rotations may be taken as typical:

Corn one year, oats seeded, clover and timothy three years, or a 5-year rotation.

Occasionally a rotation of corn, oats, clover, each one year, is used.

Corn, corn seeded the second year, clover and timothy two or more years.

Corn, oats, barley, hay two or three years.

Oats, barley, hay as long as it will grow.

Potatoes, oats, clover—a 3-year rotation.

Beans, oats, clover—a 3-year rotation.

As a general rule the 3-year rotation with one year of clover and either corn or potatoes, or both, on sod, followed by oats, will give the best results on light soils. The writer has seen unproductive meadows on light soil brought up to yields of 10 tons of silage and $2\frac{1}{2}$ tons of clover hay per acre by using a corn, oats, clover rotation, the increased yield making more manure, which in turn helped to increase the yields.

On a heavy soil the longer rotations are preferred, e. g., corn, oats, hay, three to five years, where corn will grow. Corn will grow on practically any heavy soil in Vermont provided it is drained and well prepared. The objection urged against the growth of corn on heavy soil is usually due to (1) inadequate drainage, (2) distance from barn, (3) lack of fertility because the manure usually is spread near the buildings, (4) acidity, insufficient lime content, etc. If these objections are overcome a satisfactory crop should be secured. If at too great a cost, the corn crop may be omitted on distant fields, or the soil may be turned to pasture or the field sold.

TWO ROTATIONS ON ONE FARM

While usually it is possible to include the entire tillable area in one rotation, yet at times it may be best to employ two distinct rotations; a short rotation on light soil, or near the buildings, employed to furnish forage for the silo, and a longer rotation on heavy soil or farther from the buildings. Considerations of economy in doing the work and of probabilities as to yields naturally will control.

ADAPTATION OF ROTATION TO SOIL

It may happen that a certain field is not adapted to corn, whereas the remainder of the tilled area is well fitted to this crop; yet the entire farm can be put in rotation. In the year in which corn naturally would be placed on this field it can be repeated on the area thus used the preceding year, and oats sown on the field ill-adapted to corn. The fol-

lowing table may serve to explain this method of arranging a rotation. A 5-year rotation of corn, oats and hay for three years will be used. The perpendicular columns relate to a given year and the horizontal lines to a given field. It is assumed that field 5 is ill-adapted to the growth of corn.

CROPS GROWN IN YEARS INDICATED

Field number	1915	1916	1917	1918	1919	1920	1921
1	Corn	Corn (2)	Oats	Hay (1)	Hay (2)	Corn	Corn (2)
2	Oats	Hay (1)	Hay (2)	Hay (3)	Corn	Oats	Hay (1)
3	Hay (1)	Hay (2)	Hay (3)	Corn	Oats	Hay (1)	Hay (2)
4	Hay (2)	Hay (3)	Corn	Oats	Hay (1)	Hay (2)	Hay (3)
5	Hay (3)	Oats	Hay (1)	Hay (2)	Hay (3)	Hay (4)	Oats

NOTE.—The figures in parentheses following the words "hay" or "corn" indicate the number of years the crop has been grown on the field.

The regular 5-year rotation is pursued on fields 2, 3 and 4. Corn naturally would be placed on field 5 in 1916 and oats on field 1; but since field 5 is ill-adapted to the growth of corn, in order to meet this situation corn is grown for a second year on field 1 and oats are grown on field 5. The oats which normally would have been grown on field 1 in 1916 are grown a year later in 1917, the grass is sown a year later for growth in 1918 and 1919 and the third year in grass on field 1 is omitted. In 1921 the history of 1916 is repeated; corn reappears on field 1, while oats are sown on field 5. In this way field 5 grows hay for four years and oats for one year, while on field 1 hay is grown for two years instead of three and corn two years instead of one.

ALFALFA IN A ROTATION

In view of the present day interest in alfalfa, it is well to plan how best to include alfalfa in the rotation. Alfalfa must remain for from three to five years in order that one may secure the full advantage of its growth. It does not seem likely that it will ever fully replace grass and clover in Vermont. One field will be in alfalfa and the regular crops will be grown on the other fields. At the end of four or five years, when the alfalfa begins to thin out, the field then sown to oats or barley should be seeded to alfalfa. If a good stand is secured the old alfalfa field will be plowed up and put into the regular rotation and alfalfa continued on the field where it is newly seeded.

In the following table a 4-year rotation of corn, oats and hay for two years is practiced, with alfalfa on the fifth field. The rotation is shown in operation the first year. In 1918 oats are seeded to alfalfa, or alfalfa is seeded after the oats are cut early for hay. In

1919, corn is put on the old alfalfa sod. This leaves hay for three years on fields 1 and 3 but gives the proper areas of each crop each year.

Field	1915	1916	1917	1918	1919	1920	1921
1	Corn	Oats	Hay (1)	Hay (2)	Hay (3)	Corn	Oats
2	Oats	Hay (1)	Hay (2)	Corn	Oats	Hay (1)	Hay (2)
3	Hay (1)	Hay (2)	Corn	Oats seeded to alfalfa	Alfalfa	Alfalfa	Alfalfa
4	Hay (2)	Corn	Oats	Hay (1)	Hay (2)	Hay (3)	Corn
5	Alfalfa	Alfalfa	Alfalfa	Alfalfa	Corn	Oats	Hay (1)

It is difficult to work in a long time crop like this with a few fields unless it takes the entire place of hay, in which case a new field would be seeded to alfalfa each year and the rotation would be expressed as corn, oats, alfalfa four years, or in some similar manner.

WHAT TO DO WHEN A SEEDING FAILS

Unfavorable conditions occasionally will prevent a catch of grass seed. By midsummer it can be determined surely whether the seeding is likely to be a success or a failure. In the event that results are unsatisfactory, recourse may be had to any one of several procedures.

1. The land may be disced and seeded afresh in late August or early September.

2. It may be disced as indicated in the last paragraph, and the seeding with grass delayed until the frost goes out in early spring. A favorable season will be required to give a good hay crop the first year by this method. The catch of seed, however, is reasonably sure where lands are not flooded.

3. The entire rotation may be repeated the next year, growing grain and seeding over again where seeding failed.

4. The rotation may be continued on other fields and an annual hay crop grown on the land where seeding failed, e. g., vetch, Canada peas, oats and peas, millet.

The use of some one of these methods should meet the objection frequently raised that loss of seeding prevents proper rotation.

PASTURE IN ROTATION

Where pasture is desired in a rotation it may be introduced during the last year or two years, in which instance the entire rotation will be lengthened. For example, if a 5-year rotation of corn, oats, hay three years, is modified to include pasture, it may be made corn, oats, hay, hay, pasture, keeping a 5-year period but reducing the area of

hay ; or it may be made corn, oats, hay for three years, and pasture for one year which necessitates six years and six fields and does not reduce the area of hay as much as the plan just suggested ; or pasture may be treated as was the alfalfa (p. 454), keeping it in a separate field for from three to five years, then turning a 3-year meadow to pasture and plowing up the pasture field to include it in rotation.

If hog pasture is desired, a short rotation that includes clover or rape as the pasture for the hogs will prove most satisfactory. Three one-acre fields located near the buildings can be used as a corn, oats, clover pasture rotation.

ROTATIONS WITH UNEQUAL AREAS OF DIFFERENT CROPS

All the examples of rotation given thus far have been worked out on the assumption that the relation between areas of crops was capable of expression in terms of an entire field, that the area of oats equalled the area of corn, and that the area of hay was either one, two or three times the area of corn. Instances may arise where the farmer wants areas of crops that do not allow any grouping which will give an entire field to one crop. If we bear in mind the requirements of a good rotation this difficulty usually can be met, unless the areas desired are contrary to all principles of a good rotation.

The method of procedure is as follows: The areas of the several crops desired are added, and the total divided by 3, by 4 and by 5 in order to determine the size of the fields required for a 3-year, for a 4-year and for a 5-year rotation. The crops desired are then grouped tentatively using this data as to field sizes in order to note the effect on complexity, cost of seeding and labor required. Of course soil types are taken into consideration. The 5-year rotation would be preferable for medium to heavy soils, and the 3-year rotation for light soils. Care should be taken that no part of the rotated area remains up from sod too long, and in general an attempt should be made to fit the scheme into the requirements set forth on pages 448 to 451.

Assuming a requirement of hay 22 acres, corn 10 acres, potatoes 3 acres, oats 17 acres, a total of 52 acres will be employed which would make three fields of 17.3 acres each for a 3-year rotation, four fields of 13 acres each for a 4-year rotation or five fields of 10.4 acres each for a 5-year rotation. For illustration the 3-year rotation may be taken.

Field area	1915	1916	1917	1918
I 17½ acres	Corn, 10 acres Potatoes, 3 acres Hay, 4½ acres	Oats, 17½ acres	Hay, 17½ acres	Corn, 10 acres Potatoes, 3 acres Hay, 4½ acres
II 17½ acres	Oats, 17½ acres	Hay, 17½ acres	Corn, 10 acres Potatoes, 3 acres Hay, 4½ acres	Oats, 17½ acres
III 17½ acres	Hay, 17½ acres	Corn, 10 acres Potatoes, 3 acres Hay, 4½ acres	Oats, 17½ acres	Hay, 17½ acres

This rotation locates the oats in one field, the hay in two fields, and the corn and potatoes together on a part of a field with hay. Four and one-third acres of oats will be put on sod, while 13 acres follow corn and potatoes; for a long series of years 4½ acres of each field will not be used by a tilled crop unless the corn and potatoes are grown the other side of the field where the second cycle of the rotation occurs; 17½ acres will be seeded to hay each year. This rotation works well on sandy soil, or where clover is grown.

The 4-year rotation may be considered next.

Field area	1915	1916	1917	1918	1919
I 13 acres	Corn, 10 acres Potatoes, 3 acres	Oats, 13 acres (9 acres seeded)	Oats, 4 acres (seeded) Hay, 9 acres	Hay, 13 acres	Corn, 10 acres Potatoes, 3 acres
II 13 acres	Oats, 13 acres (9 acres seeded)	Oats, 4 acres (seeded) Hay, 9 acres	Hay, 13 acres	Corn, 10 acres Potatoes, 3 acres	Oats, 13 acres (9 acres seeded)
III 13 acres	Oats, 4 acres (seeded) Hay, 9 acres	Hay, 13 acres	Corn, 10 acres Potatoes, 3 acres	Oats, 13 acres (9 acres seeded)	Oats, 4 acres (seeded) Hay, 9 acres
IV 13 acres	Hay, 13 acres	Corn, 10 acres Potatoes, 3 acres	Oats, 13 acres (9 acres seeded)	Oats, 4 acres (seeded) Hay, 9 acres	Hay, 13 acres

The crops are grown in four fields but in six subdivisions, the oats in two fields, the hay in two fields, and the corn and potatoes in one field, as in the 3-year rotation. According to this plan each field is in a cultivated crop once in four years. Nine acres of oats in one field, and 4 acres in another field are seeded, making 13 acres seeded each year. Four acres of hay follow oats, whereas in the 3-year rotation 4 acres of oats followed hay. The oats will average slightly better after oats, after cultivated crops than they will after sod. This 4-year rotation provides that 9 acres of hay are down for two years, whereas in the 3-year rotation previously discussed, 4 acres are down for two years. Thirteen acres are seeded instead of $17\frac{1}{3}$ acres, a saving of $4\frac{1}{3}$ acres. If the soil were medium heavy and timothy were used in seeding, this 4-year rotation would be slightly better than the 3-year rotation.

In a similar manner the 5-year plan could be tried, and, if no more complicated than the rotation just discussed, probably would be still better adapted to heavy soils.

ADJUSTMENT OF A FARM WITH ISOLATED FIELDS TO ROTATION

One of the problems to be faced on many farms, is the fact that fields are separated by brooks, ravines and ledges in such a way that it is impossible to make them of a uniform size for a definite rotation. This situation can be overcome so far as the rotation is concerned by so planning that certain of the present field areas always may be taken as a unit, being handled together in any given year in the rotation. Thus oats may be grown on three small fields one year; the next year all three fields will be in hay, and after two or three years of hay will be planted with corn. The fields are separated for all time by nature, but are a unit in the kind of crop grown upon them. With this principle in mind, it should be possible to reorganize any farm, however it may be cut up, and to establish a definite rotation.

A further problem to consider is how to establish the crops, once their area and grouping is determined. In doing this the yearly forage needs of the farm must be met. Too much plowing or too much seeding cannot be done in one year. It may take two or three years to get the rotation fully under way. One example will help to clear up both of the above points.

A farm has six fields totalling 54 acres which cannot be combined. Their areas and present crops are as follows: Field 1, 6 acres of oats seeded and 5 acres of clover; field 2, 19 acres of poor hay; field 3, 6

acres of hay ; field 4, 10 acres of corn ; field 5, 5 acres of hay ; field 6, 3 acres of hay. The farmer wishes to establish a 5-year rotation of corn one year, oats one year, and hay three years. This would give five fields of 10.8 acres each.

Old field number	This year's crop	New field designation	1916	1917	1918
1	6 acres oats seeded 5 acres clover	A	6 acres new seeding 5 acres clover (2nd year)	11 acres hay	11 acres hay
2	19 acres hay }		11 acres corn	11 acres oats	11 acres hay
6	3 acres hay }	C†	11 acres hay	11 acres corn	11 acres oats
3 5	6 acres hay } 5 acres hay }	D	11 acres hay	11 acres hay	11 acres corn
4	10 acres corn	E	10 acres oats	10 acres hay	10 acres hay

*Eleven of the 19 acres of field 2.

†Eight of the 19 acres of field 2 together with the three acres of field 6.

In the new grouping, field 1 is left as one 11-acre field A ; 11 acres from old field 2 form new field B ; 8 acres of old field 2 and the 3 acres of field 6 are cropped together as new field C ; fields 3 and 5 are cropped as new field D ; and the 10-acre field 4, constitutes new field E. Under this new grouping there are four fields of 11 acres each and one of 10 acres. The diagram indicates the arrangement of the crops. At the end of 1917 the rotation is thoroughly established and on each field group crops will be grown in the regular order. The crop on new field E will be one acre short, but that is unavoidable without dividing the crops into many more small areas ; and it is not a serious matter.

HOW TO DECIDE UPON THE AREAS OF EACH CROP NEEDED

1. As in the case just cited, the available land should be divided uniformly into four or five fields and fitted to a definite rotation. An appropriate number of animals to fit this plan should be kept and the surplus crops sold.

2. An estimate should be made according to the requirements of the stock kept, of the amounts of crops required for cows and horses, and of the average production per acre. With these data in hand one may determine approximately the number of acres of each crop needed to furnish the feed, adding an extra acre for good measure in case of a bad year. The total feed requirements thus determined should be

checked with the available area. If a few acres are left they may be devoted to some sales crop, and the rotation established according to the method outlined on page 456 for unequal areas of crops.

CONCLUSION

Crop rotation is not a complicated theory, but, rather, a well founded practice. It represents the application of business methods to the solution of the problem of the maintenance of soil fertility. Crop rotation, crop husbandry, and the wise usage of farm manures; these three go far towards making agriculture a business and not a job.

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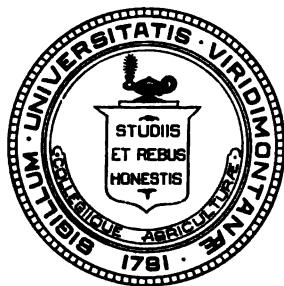
BULLETIN 191

University of Vermont and State Agricultural College
Vermont Agricultural Experiment Station
BURLINGTON, VERMONT

THE RED ROT OF CONIFERS

by F. H. ABBOTT

(Vermont forestry publication 19)



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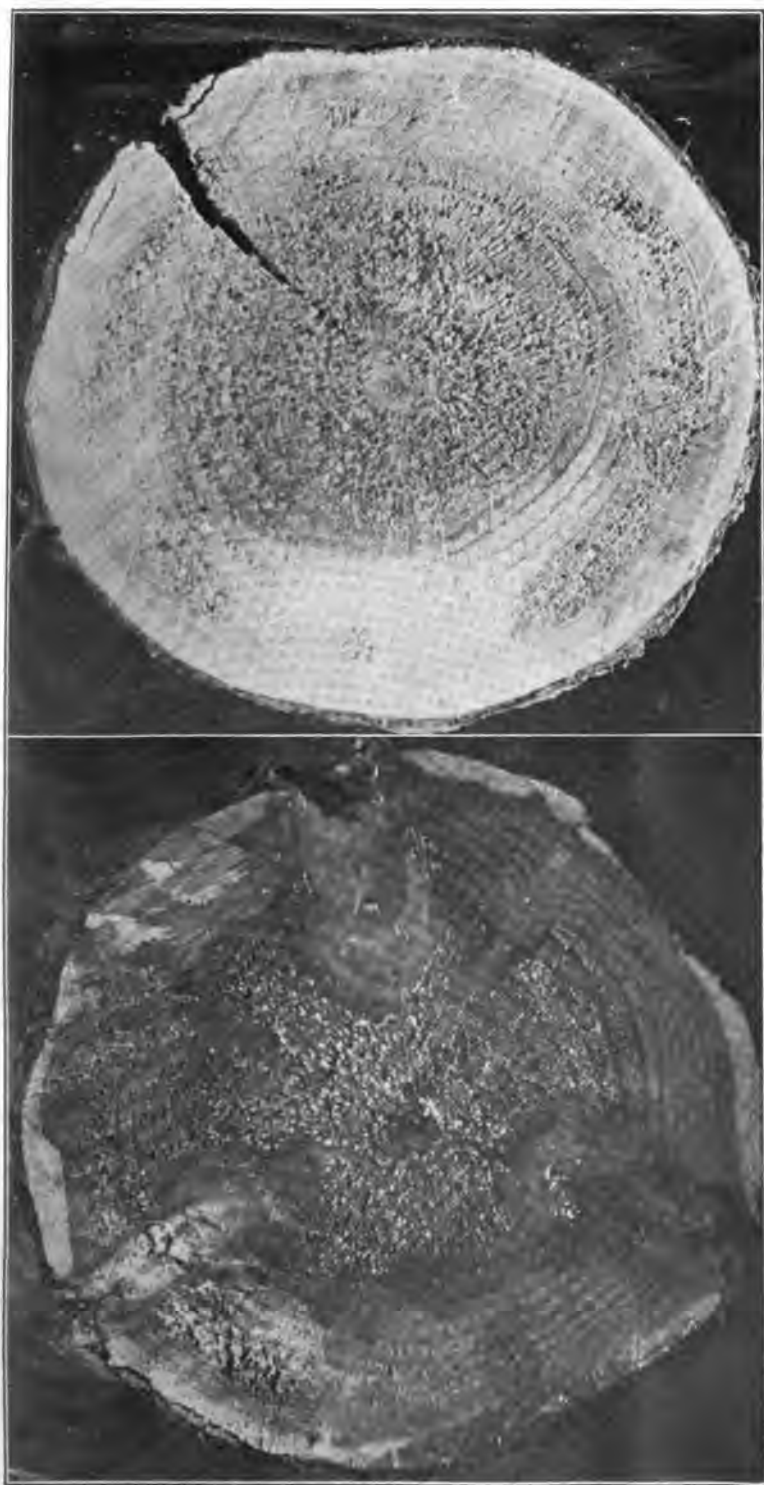


PLATE I. Cross section of eight-inch pine showing permeation of sap-wood by the fungus (upper). Cross section of diseased pine (lower).

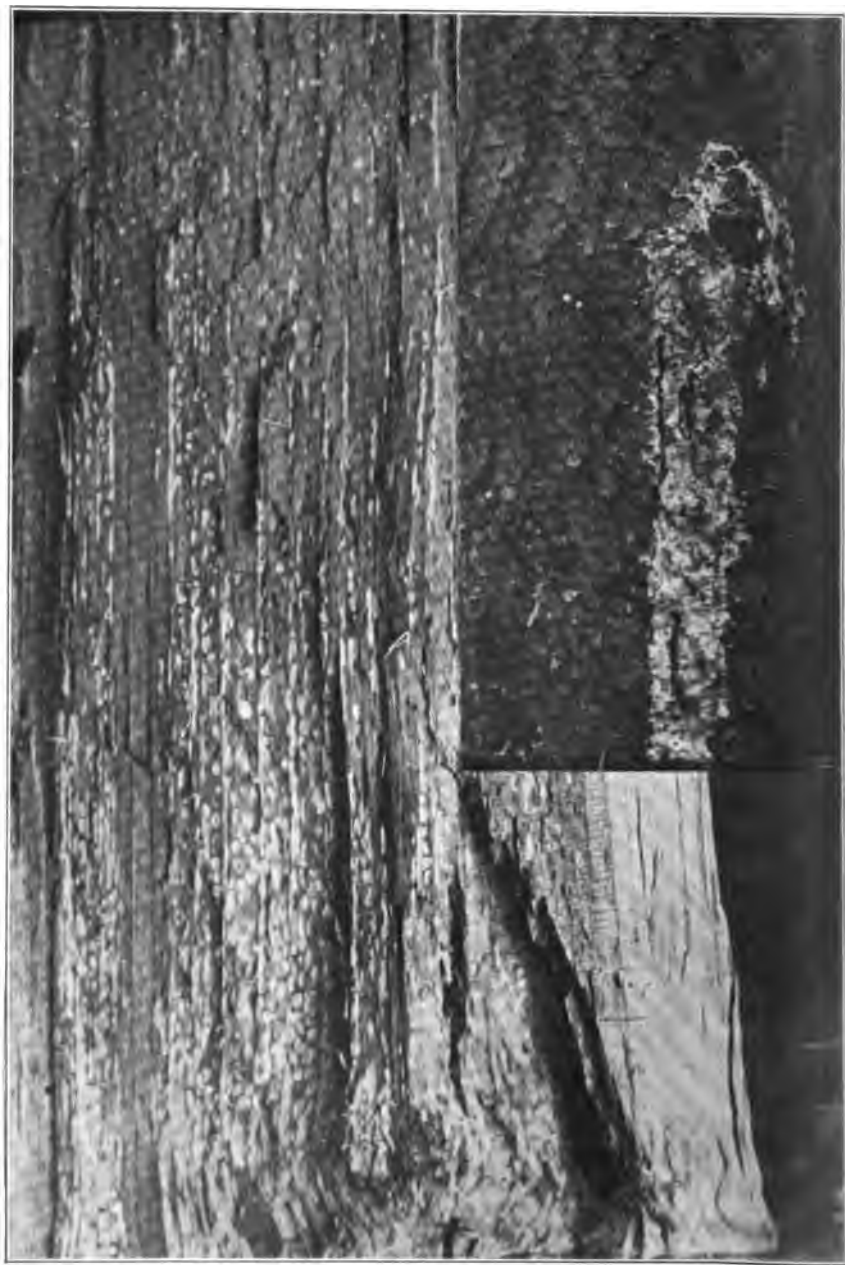


PLATE II. Longitudinal section of pine showing appearance of infected wood (main view). Fruiting body of *Trametes Pini* on a fourteen-inch pine, together with pitch exudate below fruiting body (in upper right hand corner).

19-102
1924
BULLETIN 191: THE RED ROT OF CONIFERS

By F. H. ABBOTT¹

SUMMARY

The so-called red rot of conifers is caused by the fungus *Trametes Pini*, which is primarily a parasite, assuming more or less the characters of a saprophyte when the tree falls. The fungus commonly attacks five species of conifers: tamarack, pine, hemlock, spruce and balsam. Its ravages are greatest in unthinned stands, especially pure stands of white pine.

Infection occurs mainly through broken branches which expose the heart-wood. Root infection is doubtful. Sporophores are the principal means of spreading the disease. They form on all host species but vary in form from an incrustation on the spruce and balsam to a bracket or hoof on pine and tamarack. They exist on both standing and falling trees. The mycelium spreads more rapidly up and down the trunk than across it. The damage to the wood is wrought by the solution of its lignin content by the enzym of the fungus. This damage appears to cease when the tree falls.

Laboratory cultures of the fungus from various sources exhibited uniformity. Spores were not produced in the cultures, at least up to six months. Successful cultures may be made on sterile wood.

Prevention is best effected by proper thinnings, removing diseased trees and destroying fruiting bodies.

The weight, breaking and crushing strengths of the woods were decreased approximately in proportion to the permeation of the wood by the fungus.

The red rot of conifers damages Vermont timber owners annually to the extent of about a quarter of a million dollars. The diseased wood is used in the manufacture of boxes, tubs, wooden pails, etc.

¹The writer expresses his appreciation of the assistance he has received from Arthur S. Graves of Yale University, B. A. Chandler of the Vermont Forestry Department and from the Station Forester and Plant Pathologist in assembling the data and in preparing this paper. The collection of references was facilitated through the assistance of Ferley Spaulding of the United States Department of Agriculture. Valuable specimens were contributed and field observations made by Mr. Chandler. The collection of the data regarding losses in the mills and woods was accomplished only through the cordial cooperation of landowners, millowners and operators. C. G. Hedgecock of the United States Department of Agriculture also assisted in the identification of sporophores and diseased wood.

I. FINANCIAL LOSSES

According to the 1910 census report, reviewed by the United States Forest Service in Vermont Forestry Publication No. 11, "Wood Using Industries of Vermont," Vermont produces lumber, lath and shingles from pine, spruce, hemlock, tamarack and fir, totaling 194,273,000 board feet. Were this all sound timber, free from red rot and other defects, it would average at the mill \$20 per thousand square edged. As a result of the writer's inspection of lumber in twenty mills and yards in various parts of Vermont in the spring of 1913, it is estimated that on account of the red rot nine percent of this total is reduced to a grade worth approximately \$10 per thousand. In other words, on a total of 17,484,570 board feet of timber affected by red rot, there is an annual loss of \$174,845.

But this is not all. These figures are taken at the mills and shipping points and do not represent the lumber before it is marketed. Much of the timber—calculated, from observation in the woods and estimates by lumbermen, at 2 percent of the actual cut in the woods—is so badly diseased with red rot as to be entirely useless. This, of course, never is hauled from the stump. Basing the calculation on the census figures and for the total output, this absolute loss of 2 percent totals 3,885,460 board feet. Sound logs to this amount would be worth in the woods approximately \$25,000. In addition to these losses there is the great loss to trees which become diseased and are dying constantly in the forests, eventually falling to the ground and rotting. The total annual loss to Vermont timber owners due to the red rot disease, therefore, may be placed approximately at a quarter of a million dollars.

The percentages used in this calculation were averages taken from data collected in person by the writer from actual mill tallies, observations and quarter-acre circle tallies made in the woods, and from figures and estimates furnished by mill owners and operators throughout northern Vermont.

Investigations made by the writer indicate that in white pine lots there was a loss of 8 percent of value due to the disease; in pure spruce 3.5 percent; and in mixed conifers, 5 percent.

II. EXTERNAL EVIDENCES

To the lumberman or wood-chopper the evidence of the presence of red rot in a standing tree in the forest is unmistakable. If a glance

at its general appearance does not tell him, he sounds the tree with his axe to see if it is worth felling. To the untrained person, however, considerable observation is necessary to judge with any degree of accuracy whether a tree is or is not diseased. Of course the discovery of a fruiting body (Plate III) is a sure indication, but aside from this evidence one can judge only from general appearance. Perhaps the most reliable indication, at least in the pine and spruce, is the abnormal exudation of pitch or resin from old knot-holes, or, if the disease has progressed far enough, from other points on the bark. This pitch drops down the sides of the tree and is very noticeable, as is shown in Plate II, upper left hand corner. If the fungus has invaded the trunk of the tree sufficiently to affect its health seriously, a general paleness of the bark and even of the foliage ensues. These evidences are not confined to any particular part of the trunk. The very first stages of the disease are betrayed by this pitch exudate. Suspected trees manifesting these early evidences of the malady were cut, which, upon internal examination, revealed only the red color of the heart-wood, which is the result of the first structural change brought about by the fungus. Later in the progress of the disease all the external evidences become intensified so that advanced stages are detected more easily.

III. SPECIES AND CONDITION OF TYPES ATTACKED

Susceptibility of species. Red rot is found commonly in the five soft wood species: pine, spruce, hemlock, balsam and tamarack. Von Schrenk (2) states that "of the five trees the tamarack seems to be the most readily attacked, the spruces come next and the balsam fir last." Although tamarack is not as plentiful in Vermont as the other species, the writer's observations tend to confirm Von Schrenk's statement as to its susceptibility. In regard to other species, however, the writer's study of his data leads him to conclude that, in Vermont at least, white pine is second in susceptibility, while spruce, hemlock and balsam are susceptible to invasion in about the same degree. It was noted that spruce in mixed stands appeared more prone to attack than when growing in a pure spruce stand. This is not easy to explain, unless it may be due possibly to better self-pruning and to more healthy and favorable silvicultural conditions.

Pure white pine stands showed greater amounts of red rot than did any other type. Where the disease was present at all in the white

pine, it seemed to be distributed much more uniformly than in the mixed stands.

Silvicultural conditions. Certain silvicultural conditions appeared to favor the presence and spread of the disease. It was predominant especially in tracts which were in need of thinning. A notable case of this sort was found in Orange County where the trees ranged from 6 to 14 inches in diameter at breast height and were growing so closely together that the wind had broken many branches. The heavy mass of crowns did not allow the entrance of sunlight, which is an important factor in the healthy growth of a forest.

Topography. So far as could be determined, the effect of topography upon the presence of the fungus seems very slight. The reports of lumbermen on this point were variable and evidently were governed by local conditions. Comparison of the opinions of lumbermen in different localities, strengthened by the writer's observations in the woods, leads to the conclusion that red rot lumber is as common on high rocky land as in the swamps and lowlands, with the exception of tamarack which, of course, occurs only in lowlands.

Wind. It is believed that the wind is a more important factor than topography. Areas exposed to heavy winds show more red rot decay than do sheltered stands. This condition might be explained by the fact that the damage done by the wind in breaking branches leaves open places or branch wounds where the fungus may enter the tree. The wind also aids in carrying spores from one tree to another.

Age. Previous writers have ascribed much importance to the supposed fact that only the oldest trees in the stand are affected. While this may be true in some sections, many specimens of trees not more than 25 or 30 years old were found by the writer to be infected. Von Schrenk's statement that the fungus attacks living trees only after they have reached the age at which they form heart-wood, probably is a more correct conception of the matter.

IV. DISTRIBUTION

Numerous German references report the occurrence of this fungus in all parts of that country where any considerable stands of coniferous trees are found. Möller (5) says "It is present wherever the conifers grow in any abundance and the damage caused by it reaches into the millions of dollars annually." Hartig (1) states that it is very abundant in the pine woods of North Germany and occurs also, but less

frequently, in the spruce woods of South Germany. That it affects the conifers in other eastern countries is evidenced by the report of Khan (6) on its occurrence in India in 1904.

Von Schrenk (2) has reported in a general way on its occurrence in Maine and other New England states on white pine, red spruce, white spruce, hemlock and tamarack. The parasite attacks living trees after they have reached the age at which they form heart-wood, and honeycombs the wood in such a way that it appears to be filled with small holes, many of which seem to have a slimy white lining.

The writer has tried to secure information which would afford accurate data concerning its occurrence in Vermont, by the collection of statistics from different parts of the State. The percentages of disease in spruce and mixed stands appear to be fairly uniform in all places where data were obtained. With the exception of a few local situations, either badly infected or entirely free from disease, one may expect to find in most cuttings losses varying from 3 to 5 percent.

The presence of the disease, however, was not as uniform in pine trees as in the others mentioned. Many small tracts, especially isolated ones, were found where no disease was apparent. On the other hand other places were found where many trees were affected and the loss was very large.

With the exception of the Passumpsic valley, which appears to be excellent pine land, and where very little red rot was found, the distribution of the disease is irregular. Along the shore of Lake Champlain, tracts less than ten miles apart were located where both extremes of conditions were found. The Connecticut valley shows a similar condition.

It is the writer's opinion that the best pine lands show the greatest freedom from disease because the more rapid and uniform growth results in better self-pruning and healthier general conditions.

V. THE FUNGUS

Name. The fungus causing the red rot of conifers is one of the Basidiomycetes, *Trametes Pini*. It is a parasite of growing coniferous trees and assumes the characters of a saprophyte, (that is to say, a fungus living upon a dead plant or animal) to a greater or less extent upon the death of the tree, so long as the moisture and food contents of the host remain favorable to its development. The question of its adaptability to a saprophytic mode of life is one of much economic im-

portance from the point of view of its ability to continue the formation of fruiting bodies on fallen trees and thus greatly to increase the spread of the disease.

Growth of mycelium. Von Schrenk (2) states that destruction of the wood, at least, ceases upon the fall of the tree, but that whether the fruiting bodies on fallen trees do or do not function to any great extent remains an open question. That the growth of the mycelium (the thread-like tubes which penetrate the wood and nourish the fungus, tubes which in their function are analogous in a way to the roots of higher plants) in fallen trees is dependent almost entirely upon moisture conditions, was proved conclusively by the writer by taking uniform slabs of diseased pine, placing them in various conditions of moisture and watching the progress of the growth of the mycelium and the destruction of the wood. Slabs placed under cover where conditions are such as are found ordinarily where lumber is seasoned, showed no further growth of the fungus. The wood dried out and its pithy appearance assumed a more open character. On the other hand, slabs of the diseased wood left in contact with the ground, or near moisture, showed abundant growth of the mycelium, which extended even to the surface of the wood. Whether infected wood left in such conditions ultimately would or would not form functioning fruiting bodies, is undetermined. However, it is believed that trees which fall in the woods as a result of permeation by the fungus do not fall ordinarily under such conditions as tend to favor the continued growth of the mycelium. The trunk of the tree is more likely to be attacked by fungi such as *Lenzites sepiaria* and other saprophytes that can live in a drier situation.

Method of attack. Any tree wound which opens up a way to exposed heart-wood enables the red rot fungus to germinate and the mycelium to penetrate the wood. Once the mycelia have gained entrance, they spread rapidly, both up and down the trunk, along the tracheids (i. e. wood cells used simply as water carriers) longitudinally, and more slowly across radially.

Resistance. Apparently the only resistance offered by the tree takes the form of a free exudation of pitch. In the younger trees this discharge is sufficiently large to hinder the progress of the mycelium while the lessened amount of pitch which is exuded by the older trees accounts for the increased destruction.

It is stated by Von Schrenk (2) that the mycelium of *Trametes Pini* flourishes in both the heart-wood and sap-wood of spruce, hem-

lock, fir and larch, while in pine it grows only in the heart-wood. That the latter is not always true is shown in Plate I of a cross section of an eight-inch pine, in which it will be noticed that the destruction has continued irregularly into the sap-wood. This specimen was taken from a standing tree upon which a fruiting body was found.

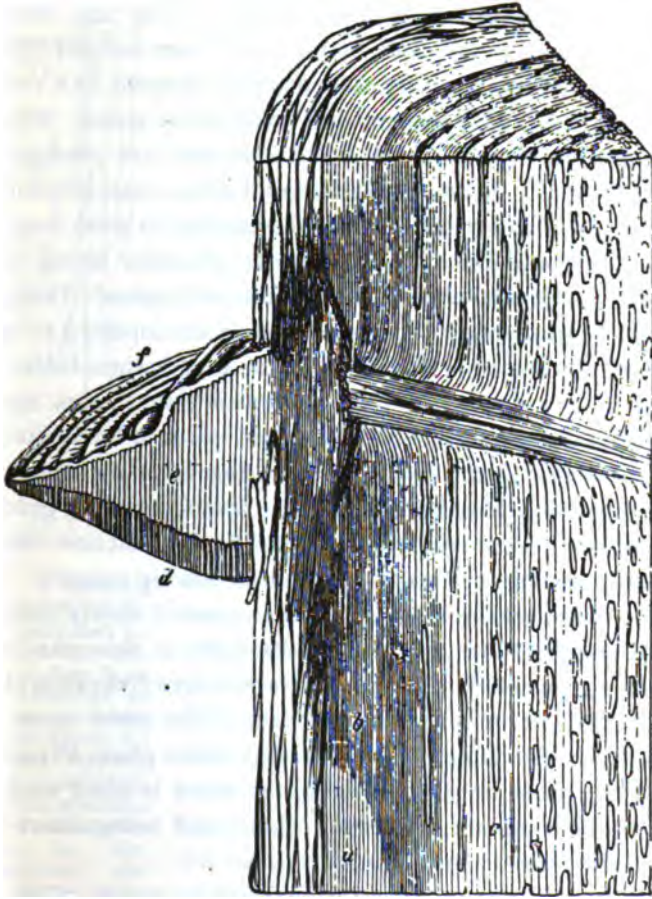


Figure 1. Part of stem of a pine bearing sporophore of *Trametes Pini* (one half natural size) (After Hartig).

Hartig (1) says the fungus cannot enter through old branches naturally pruned. This point was investigated and it was found that the tree forms a natural protection for itself. When the branch dies the free exudation of pitch causes that part which lies adjacent to the cambium, (the growing tissue just inside the bark), as well as that inside the tree to become hardened and impenetrable. This con-

dition is shown clearly in Figure 1, which is a longitudinal section of a diseased pine, cut squarely through the center of the knot. It will be noticed that the fungous growth is present in the vicinity but does not penetrate this resinous wood of the old branch.

Morphological characters; wood dissolution. The visible effects of the growth of the fungus in the wood are described by Von Schrenk (2) for spruce in part as follows: "The first effect to be noticed is a change in the color of the wood from natural light straw color to a purplish gray. Very soon this gray deepens to a red brown. Black lines precede the appearance of small white areas. These areas usually are some distance from each other and are arranged longitudinally (Plate II). Some of the holes fill with a mass of white fibers. As the holes grow in number and size they appear to unite longitudinally rather than radially. As the disease advances in the tree, the destroyed cells fill with a dark brown mass of hyphae¹. These hyphal plugs occur in nearly every tracheid and are accompanied by a brown incrustation which dissolves in part in dilute potassium hydroxid and entirely in warm nitric acid. These incrusting substances apparently were decomposition products and were laid down in liquid form.

"The changes in the cell walls resulting from the attack of the mycelium are fully described by Hartig (1). There is a gradual extraction of those elements which give a lignin² reaction due to the probable secretion by the fungus of lignin-dissolving enzymes.³ This begins in the tertiary lamella and proceeds outward slowly through the secondary lamellae. The primary lamella splits at this state and dissolves, leaving the individual tracheids entirely free from each other and composed approximately of pure cellulose. The white spots are the points at which the change to cellulose has taken place. Preceding the change of the wood fiber to cellulose, the wood is filled with masses of hyphae which become masses in centers and bring about the dissolution of the wood.

"The hyphae grow out from the original centers in all directions, proceeding faster up or down the stem parallel to the tracheids than they do across them. It is the opinion of the writer that the decomposition products cause the destruction of the wood to stop at this point. In the newly invaded trunks the mycelium is colorless. The hyphae are somewhat thick walled and have numerous short branches which penetrate the walls in all directions."

¹ The term "hyphae" as used here, is synonymous with mycelia.

² The woody substance of the cell wall.

³ An enzym is a ferment possessing the power to decompose organic compounds.

Figure 2, copied from Hartig, shows more clearly than can be explained the appearance of the mycelium in the tracheids and the gradual solution of the lignin brought about by the enzym of the fungus.

VI. CULTURAL STUDIES

Specimens of diseased wood were secured from several sections of the State, though mostly from forests near Burlington, in August, 1912, the trees being in various stages of decay. These specimens were examined microscopically and the fungus was grown on lima bean agar (Clinton's formula) and a synthetic agar composed of peptone and the necessary salts, which was strongly acid in its reaction.

Inoculation methods. Some samples for inoculation were taken from standing trees on which fruiting bodies had developed, others from logs or sawed lumber in lumber yards, and in two cases successful cultures were made from particles of wood taken from a knot-hole in a suspected pine upon which no fruiting body could be found. The mycelia obtained from all these sources showed noticeable uniformity in their growth or media. Particles of fruiting bodies also were used for inoculations and, in comparison with each other and the cultures made directly from wood, gave equally uniform results.

Most of the inoculations were made directly from the specimens of wood. By carefully handling the specimens with sterile forceps and cutting away the external portions of the wood with a sterile knife, small particles of the diseased wood fiber were obtained, which, when introduced upon the surface of the tubed media, gave about 90 percent of pure cultures.

Mycelial growth. At first the mycelium made slow growth, from

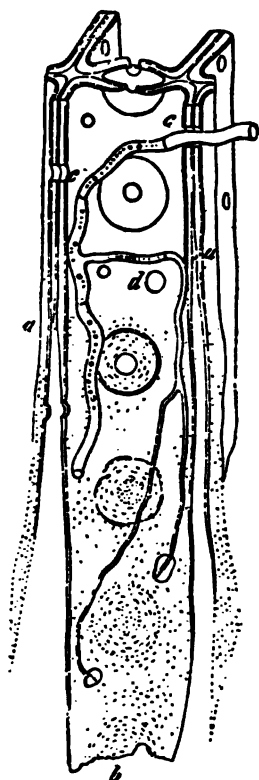


Figure 2. A tracheid of *Pinus sylvestris* which has been decomposed by *Trametes Pini*. The primary cell-wall has been completely dissolved as far as aa. In the lower portion of the figure the secondary and tertiary walls consist of cellulose alone, in which granules of lime are distinctly recognizable, b; filaments penetrate the walls and leave holes behind, d, e.

(After Hartig).

ten days to two weeks being required before visible growth could be detected in the tubes. Plate IV shows a photograph of a six-weeks-old culture on lima bean agar. During the first stages of the growth the hyphae, (that is to say, the filaments of the fungus), were pure white in color. They spread over the entire upper surface of the media, forming a mat about one-sixteenth of an inch in thickness. In no case did they penetrate the media to any extent.

Inoculations were made upon media in deep petri-dishes, about 2.5 inches deep and 3.5 inches in diameter, in order to promote a longer period of mycelial growth before the media began to dry. The growth in the petri-dishes was not essentially different from that in the tubes.

In all cases the mycelium retained its white color for a period of from six to eight weeks, then slowly turned to a brown which grew steadily darker for about eight weeks, after which time there seemed to be little increase in amount of mycelium and no change in color. The brown color exhibited so uniformly by the culture apparently is due to a sort of incrustation which is laid down about the mass of mycelium. The fact that this incrustation is soluble in part in potassium hydroxid and entirely in warm nitric acid indicates, as Von Schrenk (2) has stated, that it is due to the presence of decomposition products. This coloring matter diffused through and stained brown the lima bean agar after two months. The growths on the two kinds of media differed only in minor particulars.

Sterile wood cultures. In order more closely to follow the fungus in its attack upon wood, cultures were made in the following manner: Small blocks were sawed from each of seven different kinds of healthy wood, spruce, pine, hemlock, tamarack, balsam, birch and oak. These blocks were taken from the trunks or branches and sawed in such a manner that both heart-wood and sap-wood were present in each block. They then were put into an ordinary test tube, in the bottom of which had been placed previously a small ball of water-soaked cotton. The tubes then were plugged and sterilized. Inoculation was accomplished by introducing small particles of mycelium from previous media cultures. Growth in the dark and at room temperature started on the wood almost immediately and spread irregularly over the entire surface of the block. Eight inoculations, besides a check, were made on each kind of wood and in 95 percent of the tubes the cultures appeared pure. The fungus apparently showed no preference for the sap-wood.

Growth on different species. Comparison of the amount of hyphae

in the tubes showed that the susceptibility of the wood seemed to range in order as follows: Tamarack, pine, hemlock, spruce, balsam. This order of susceptibility is the same practically as that noted by Von Schrenk (2) in New England forests.

The inoculations made on oak and birch were successful, the fungus growing luxuriously; but the damage to the wood was done more slowly and its extent relatively was very limited. The attack of the fungus on the hard woods should be studied more thoroughly. The preliminary sterilization, of course, may have rendered them soft and also may have brought about chemical changes which rendered them more readily open to attack than when in their natural state.

The brown incrustation occurred fully four weeks later in the case of all eight cultures of the tamarack and balsam than in the cultures on pine, spruce, and hemlock inoculated at the same time. Microscopical examination revealed no essential difference in the fungus as cultivated on the different woods, except that the hyphae cells possibly were a little larger in diameter on the tamarack and smaller on the hard woods.

Influence of moisture. The growth of the fungus is profoundly affected by the presence or absence of water in the tubes. Without exception whenever moisture was lacking to any great extent, the growth of the fungus was affected directly. If water was omitted at the time of inoculation, the culture failed to develop. If the fungus grew luxuriantly in the presence of moisture it ceased its growth immediately and dried up if the water supply was withdrawn. Tubes in which this drying out process had taken place once, but slowly re-established growth upon the addition of water.

Spores. The cultures were examined microscopically at various stages for spores. The last of these examinations was made in May, 1913, and, even on cultures which had been growing since September, 1912, no trace of such reproduction could be found. The marked uniformity of the general characters of the mycelium, noticed in all the slides prepared from the different cultures, indicated that the same fungus had been isolated in all cases. The growth of the fungus on the sterilized wood cultures produced the same appearance as that taken from a diseased tree in the forest. Blocks of wood are shown in Plate IV on which the fungus had flourished for a period of six months but from which the mycelium was scraped from the wood to show more clearly the presence of the white-lined pockets which are so characteristic of the disease.

VII. EFFECT OF THE FUNGUS ON THE WOOD

The change from the natural color of the wood to a red brown has been responsible for the name of "red rot" lumber, by which woodsmen and lumbermen designate the diseased wood.

Breaking and crushing strength tests. In order to show the extent to which the changes wrought by the fungus as outlined on pages 7 to 10 take place, and to afford a comparison of diseased and healthy wood from the standpoint of the use of lumber for manufacturing purposes, tests of breaking and crushing strengths were carried out as follows: A complete section of a diseased pine log about 12 inches long was taken from a standing tree in Bradford. This tree was about eight inches in diameter and about 35 feet high. A fruiting body was found at a knot-hole four and one-half feet from the ground. A cross sectional photograph (Plate I) indicates the extent to which the fungus had penetrated the wood. This 12-inch section was seasoned in a boiler-room where it was subjected approximately to the heat employed in an ordinary kiln-drying process. The log then was sawed as economically as possible into sticks with an average measurement of 1.1 x 1.2 x 10 inches. These sticks were assorted then into three classes, according to the extent to which the fungus was present in each, as follows:

- (1) Showing very little or no evidence of disease.
- (2) Fungus growth on one or two sides.
- (3) Thoroughly ramified by the fungus.

The weight of each stick and its volume by displacement of water were obtained. Breaking strengths were determined on sticks ten inches long and crushing strengths were determined on five-inch lengths.¹

Four sets of tests were conducted for each class. A summation of results follows:

SUMMARY OF TESTS FOR THE THREE CLASSES					
Class	Volume c.c.	Weight grams	Diameter inches	Pounds to break	Pounds to crush
Free from disease	240	89	1.1 x 1.2 x 10	610	6620
Partial infestation	247	78	1.1 x 1.2 x 10	498	3910
Complete infestation	248	67	1.1 x 1.2 x 10	337	2440

This table is self explanatory. It shows plainly the relative decrease in weight and in breaking and crushing strengths proportional to the extent to which the fungus had penetrated.

¹ The strength tests were carried out in the College of Engineering under the direction of J. O. Draffin of the Class of 1918.

Clearly the fungus is capable of destroying the wood and makes it unfit for manufacturing purposes. The advisability of cutting and marketing trees affected by the disease as soon as the presence of the fungus is noted, is evident. In this way only can the timber be used at all. It should be noted that the strength of the sticks cut from disease-free wood corresponds closely to that of standard seasoned pine. This tree, as a whole, however, was affected so seriously with disease that at least 50 percent of it would have fallen into a \$10 grade, and 25 percent of it was utterly useless.

VIII. METHOD BY WHICH THE FUNGUS SPREADS THROUGH A FOREST

Root infection. According to Khan (6) an examination of various specimens of the roots of coniferous trees in an East Indian forest infected with *Trametes Pini* showed that there is a strong possibility that the disease may spread by the passing of the mycelium from the roots of diseased to those of healthy trees. Even more striking is Runnebaum's (4) statement based on the inspection of 70 infected trees, to the effect that 50 of them had been infected from the roots. A careful examination of the roots and trunks of these 50 trees, on the side on which the fruiting bodies occurred, showed mycelium up to a point only half a meter higher than the level of the ground. The infection in the other 20 trees evidently had occurred in a branch wound, because the rot was confined to the parts above ground. While this channel of infection may be open to some cases, the chances of the fungus penetrating the cambium and sap-wood of an uninjured root seem rather slight. In any case the fungus can be spread thus but slowly. The writer is of the opinion that root infection does not take place to any great extent in this locality, certainly very few of the specimens seen in Vermont were diseased below the ground. It may be that the fungus has been confused with its closely allied form, *Trametes radiciperda*, which produces much the same condition of decay in the wood but is spread solely by underground methods, its fruiting bodies forming below the surface. Tubeuf (3) has made clear the distinction between *Trametes Pini* and *Trametes radiciperda*, although the two species produce much the same condition in the wood.

Fruiting bodies or sporophores. The fungus follows in general the habits of other wood fungi and spreads through a forest mainly by the production of spores in a fruiting body, or sporophore. That these sporophores are very plentiful on the diseased trees in German forests

is indicated by the constant reference made to their occurrence by German writers. Von Schrenk (2) speaks of them as being "extremely common on all (New England) affected trees." Specimens have been collected from forests in Maine, New Hampshire, Vermont, New York, Ontario, Quebec and New Brunswick. However, the writer did not find these fruiting bodies as common, at least in Vermont, as they have been represented to be. No trace could be found on a large proportion of the infected trees, the only external sign of the disease being an abnormal exudation of pitch from knot-holes and a general pale and unhealthy condition of the foliage. However, the sporophores were found occasionally on every diseased tract.

The sporophore of *Trametes Pini* is easily distinguished from allied forms by the light red-brown color of the hymenial or fruit-bearing surface and by the regular small round pores. The pores on the specimens obtained in Vermont seem smaller than those occurring on specimens from other sections. The form of the pileus or cap varies with the species of the host plant. Hartig (1) ascribes this difference to the various amounts of resin contained in the trees of the several species. The sporophore on the pine appears characteristically in the form of a large bracket, situated on the surface of the tree where an old branch stub has broken off. Plate III shows this characteristic appearance. An exudation of pitch almost always accompanies the presence of the fruiting body. Plate III shows two specimens of fruiting bodies or sporophores collected, respectively, at Bradford and Burlington. In the case of the spruce, tamarack and fir, these characters do not hold. The form of the sporophore varies from that of an incrustation to that of a bracket, and it does not confine its location to the nodes but may develop at any point.

These sporophores give rise to the spores which are carried about by the wind until they find a suitable place for germination. Where old branches have been broken off, exposing the heart-wood before complete protection to the wound has been effected by the resinous deposit in the branch stub, the spore finds the most favorable conditions for entrance and germination. Its progress in the heart-wood is rapid, but when it reaches the resinous sap-wood its advance is slower. About this time the sporophores begin to form. Where the dead branches have been broken off close to the trunk, the hyphae grow out from the stub and form a cushion. Von Schrenk (2) has explained carefully in detail the progress of the growth of the sporophore on pine, spruce and tamarack. The cushion formed on the branch stub is very small at

first and has the appearance of being covered with velvet. The radial growth of the hyphae is rapid and a sheet is formed which adjusts itself to the shape of the stub. At the edges this sheet projects from the bark and forms an irregular shelf, the top of which after a time becomes brown and hairy and ultimately develops into a bracket formation. The growth seems to take place most rapidly through the latter part of the summer and the early fall. The hyphae at the edge of the sheet extend their area, while those forming the walls of the pores grow vertically downward. It is not known to what age one of these sporophores may attain.

Most writers call attention to the fact that fruiting bodies are common only on the larger and older trees. While this is true to a certain degree, the production of sporophores by no means is confined to such trees. The writer found that they were as common on diseased trees less than seven inches in diameter as they were on larger and older trees. One good specimen was found on a pine about six inches in diameter and only about 30 years old. The entire surrounding stand in this case was only from 45 to 50 years old and fully as large a percentage of diseased trees was detected here as in any stand examined.

These fruiting organs exist on both standing and fallen trees. Von Schrenk says: "They were found on trees which had been cut down four years before and new ones were constantly appearing." In view of the fact that the mycelium practically ceases growth as soon as the wood is placed in a position where desiccation will take place, it would seem that such sporophores could not be kept in a condition to function for any length of time after the fall of the tree, unless the tree fell in a position to cause the excessive absorption of moisture. However, it is this faculty of fruiting to a greater or less extent on dead trees which must enable this fungus to accomplish its rapid spread.

IX. PREVENTIVE MEASURES

The discovery of this disease and of its method of spread in Germany immediately led to search for some means by which its ravages could be controlled. Most students of this malady as it occurs in Europe have suggested the following procedure:

1. *Prevention of branch breaking.* Laws have been enacted to prevent wood gatherers from breaking off branches which leave an open wound in the heart-wood, thus encouraging the entrance of the fungus. These wood gatherers damage forests which lie near cities and villages. They are supposed to take only the dry dead branches,

but in so doing often remove branches which still are partly green and in which the protective layer of resinous wood has not formed.

2. *Removal of fruiting bodies.* If fruiting bodies are removed and destroyed and a disinfectant is applied to their former sites on the trees much good will be accomplished. This may be done according to Möller (5) by a crew of two or three men equipped with ladders with instruments for hewing out the sporophores and with some form of disinfectant to apply to the spots where the fruiting bodies were located. Caterpillar tar (Raupenleim) is the disinfectant commonly used in this work. Its application in this manner is known to have prevented the formation of new fruiting bodies in at least 80 percent of the cases where it was used. Kienitz (8) states that it costs about 10 cents an acre to do this work.

3. *The cleaning out of infected trees.* Infected trees can be recovered thoroughly only by a careful survey of the tracts by a man who is trained in detecting the disease. The complete removal of the whole tree is necessary because of the chances of further infection, either from the mycelium or from fruiting bodies on the fallen trees. This operation should not be expensive, as enough of the lumber cut would be worth saving to pay for the cutting. This cutting could be made best in the form of a thinning. Hollrung (7) advises a complete inspection and cleaning of an infected forest every five years in order to maintain complete control of the disease.

Obviously all these methods are radical and are applicable in their entirety only where intensive forestry can be practiced. The problem of prevention in this country assumes a different aspect because lumber prices do not permit as intensive methods as obtain in Europe and because the sporophores apparently do not grow as abundantly, in the Northern states at least, as they do in Germany.

In view of the fact that evidence points toward the probability that fruiting bodies may form and function on dead trees, it appears that the first procedure should be to remove carefully all dead and diseased wood so that it will not spread the disease. Then, secondly, over-thick plantations should be thinned.

The writer noted a significant fact in his study of Vermont forest conditions in their relation to red rot, namely, that the disease was much more prevalent in stands in need of thinning and of an improvement of silvicultural conditions than in well-handled stands. Proper thinnings should be made, if possible, in rotation. Thinnings thus



PLATE III. Sporophore of *Trametes Pini* on pine; very nearly actual size

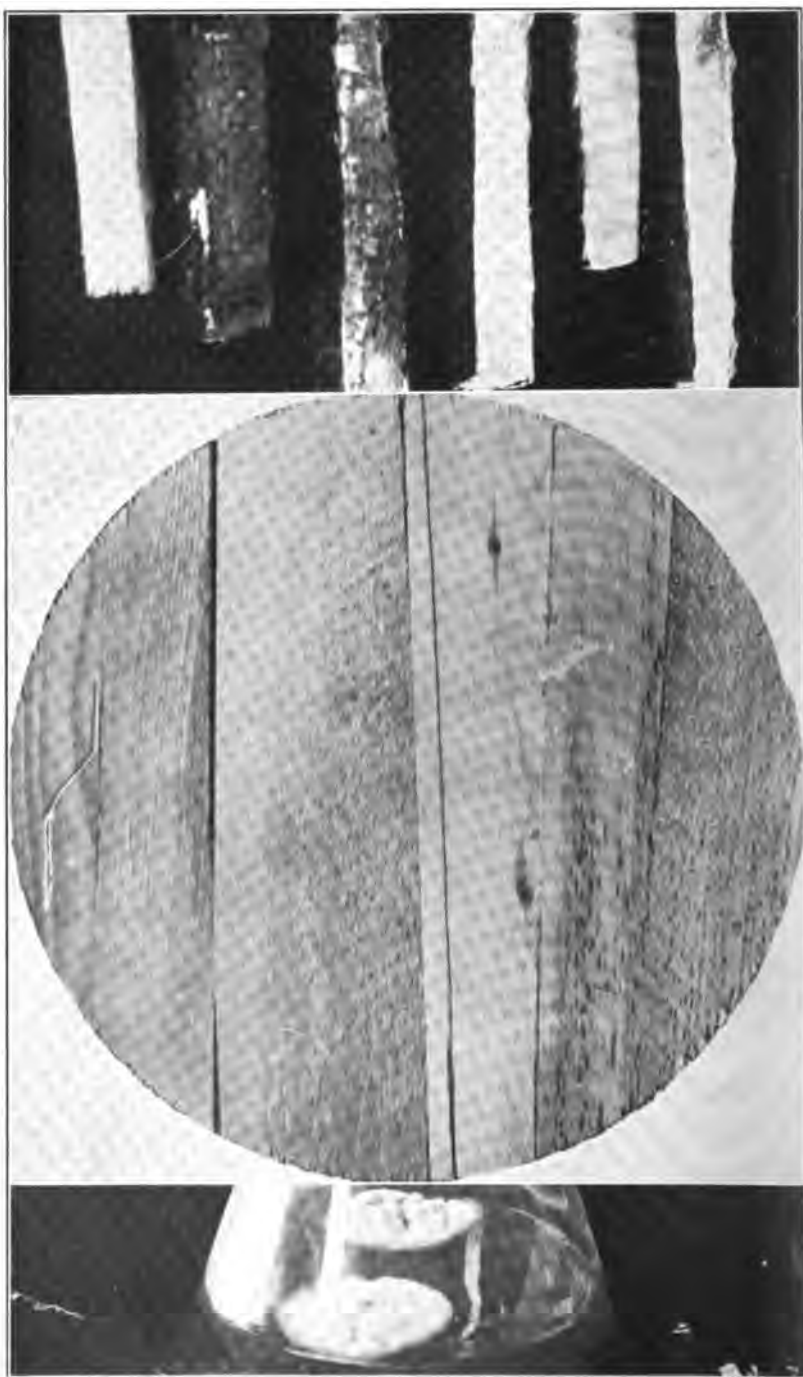


PLATE IV. Wood chips upon which *Trametes Pini* had flourished for six months. Mycelium is scraped from outside to give clearer view. From left to right: check, pine, tamarack, hemlock, spruce, balsam (upper). Butter tub cover; showing how infected wood is utilized (middle). *Trametes Pini* growing in cultures (lower).

periodically made at intervals not more than 20 years apart, should provide easily for the removal of all diseased trees. In the University forest at Burlington, where such thinnings have been carried out, a much better distribution of the trees has been effected.

The present method employed in many forests of cutting to a diameter limit, is inadvisable, because it leaves trees which may be diseased, or which may spread the disease, or trees which on the whole are undesirable from the point of view of reproduction or future lumber production. Experienced markers should be employed who understand the importance of such matters and who would be faithful in attending to the general betterment of silvicultural conditions.

Some lumbermen who have become interested in forestry have thought that they could secure reproduction of spruce by leaving trees diseased with red rot for seed purposes, thereby avoiding the financial loss incurred by leaving sound trees. Such procedure is dangerous because it tends to perpetuate the disease, not through the seed of the old trees, but by the fungus upon them.

It would be impracticable under existing American forestry conditions to attempt such operations as making a complete survey to remove and disinfect fruiting bodies, unless it were in some valuable grove where expense was not a factor.

X. USES OF DISEASED WOOD

During the writer's studies of the red rot situation in Vermont lumber yards and mills, certain interesting points were noted as to the methods employed in making use of the diseased wood, as well as to the extent to which the fungus could destroy the wood without totally impairing its value for manufacturing purposes.

Red rot lumber, as is indicated in previous pages, is considered worth about \$10 per thousand. It is defined usually as "box-board grade." Some manufacturers are able to use it in such ways that they can afford to pay as much as \$18 for it. Such lumber often is reserved by dealers for local trade. As a rule it does not pay to ship it.

The lumber graded as mentioned above, box-board grade, finds its principal use in the manufacture of boxes of all descriptions. It is not used alone but is mixed with a better grade in order to furnish a marketable product. It is used also in making pails, tubs, kegs, etc. Perhaps this is a more effective method of making use of this wood than that just cited, since much poorer lumber can be used by virtue of the

fact that a filler can be employed on the most decayed places and then the whole covered with paint to make an apparently perfect product. The photograph of a butter tub cover in the rough (Plate IV) shows the grade of lumber that can be used and also shows the proportion which can be introduced and still permit the structure to hold together.

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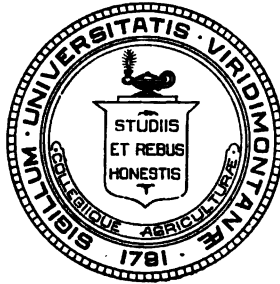
University of Vermont and State Agricultural College

Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

AGRICULTURAL SEED

by G. P. BURNS



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Director's and State Forester's offices, chemical, horticultural and dairy laboratories are in Morrill Hall at the head of Main street; botanical and bacteriological laboratories are at Williams Science Hall, University Place; veterinary laboratories are at 499 Main street.

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BULLETIN 192: AGRICULTURAL SEED

BY GEORGE P. BURNS

INTRODUCTION

Acting under the authority conferred upon the Station by No. 184 of the Acts of 1912, its sampling agents gathered during March and April, 1915, 343 samples of agricultural seed offered for sale in the open markets by local dealers, as follows:

Alfalfa	8	Timothy	53	Oats	6
Alsike clover	46	Barley	12	Orchard grass	4
Red clover	57	Blue grass	3	Peas	3
Corn	85	Buckwheat	2	Rape	1
Millet	38	Sweet clover	3	Rye	1
Redtop	16	White clover	4	Wheat	1

These official samples were drawn in the manner prescribed by the rules of the Association of Official Seed Analysts. Purity tests were made by the weight method, a definite amount of seed being taken, its weight determined, pure seed, weed seed and inert matter or dirt separated, and the weight of each determined.

The results obtained are presented in the following pages in tabular form. In the eight tables (pages 17 to 30) the data are arranged alphabetically under names of the various kinds of agricultural seed. The trade or brand names, the names and addresses of retailers and wholesalers, the guaranteed and actual purity percentages, and the approximate number of weed seeds in a pound are displayed. The amount of ergoted grain is shown in the timothy and redtop tables. The same data are rearranged alphabetically by wholesalers' names in table XIV (pages 31-39). This arrangement facilitates reference by purchasers of seed. For example, a farmer who contemplates buying timothy seed sold by the Smith Company of Smithville, Vermont, wholesaled by the Brown Seed Company of Brownsville, Texas, and desires as a guide to his purchase to know how well as a matter of fact the Brown Seed Company had lived up to its promise as to the grade of its timothy sales during the previous year, can turn directly to the data, instead of having to dig it out of the 53 analyses listed in tables VI-XIII. Furthermore, he can see at a glance the situation as to promise and performance of all the offerings of the Brown Seed Company during the preceding year as judged by station sampling and analyses. This system of alphabetical arrangement long has obtained in connection with the presentation of the analytical results in the fer-

tilizer bulletins and this year will be put into operation likewise in connection with the feeding stuff bulletins.

One hundred and ten samples of 14 kinds of seed forwarded by individuals have been analysed during the year. Since the Station cannot vouch for the authenticity of these samples, the data secured thereon are not included in the tabular statements.

THE STATE AGRICULTURAL SEED LAW

The general assembly of 1912 passed an agricultural seed law, (No. 184 of the Acts of 1912). It went into effect July 1, 1913, and became effective for the seed trade of 1914. The full text of this law appears in bulletin 183, which will be sent without charge to any address on application.

The following synopsis, setting forth in brief form and direct language the duties respectively of the wholesale seed house or purveyor, of the local dealer, and of the Station, the three parties in interest, should be helpful to all concerned. The farmer who is the ultimate consumer, although not specifically mentioned in the law, has moral if not legal duties in this connection, as is indicated on page 5.

SYNOPSIS OF THE AGRICULTURAL SEED LAW

THE WHOLESALER'S DUTIES

This enactment requires:

1. That agricultural seed—the common grasses, clovers and cereals—shall be truly named and guaranteed as to its purity and freedom from foreign matter (weed seed, chaff, dirt, etc.) and seed other than the kind sold, provided such are distinguishable by their appearance.

2. That agricultural seed shall be deemed to be “adulterated” if it contains more than one ergotized seed to the ounce or more than one seed of corn cockle and a few other weeds specified by name, unless their presence and amount are declared on the package.

3. That agricultural seed shall be deemed to be “adulterated” if its purity is substantially less than the statements made in its behalf would indicate.

4. That agricultural seed shall be deemed to be “misbranded” if it is labeled in a false or misleading manner or is not guaranteed.

THE LOCAL SEED DEALER'S DUTIES

This enactment requires:

1. That seed dealers see to it that "every lot or parcel of agricultural seed of five pounds or over sold, offered or exposed for sale" shall be truly named as to its contents and guaranteed in writing or in print as to its purity and freedom from foreign matter (weed seeds, chaff, dirt, etc.) or seeds other than the kind sold, provided such are distinguishable by their appearance.

2. That seed dealers see to it that they sell no seed which is adulterated or misbranded within the meaning of the law (see 2, 3 and 4, above). Local dealers who feel that they cannot know some of the facts as to adulteration may, if they will, protect themselves by securing written statements from the wholesalers from whom they buy, as provided by section 6 of the act.

THE STATION'S DUTIES

This enactment requires:

1. That the Station test, at specified fees, seed samples submitted for test of purity, using the funds thus received for the purposes of the act.

2. That the Station sample agricultural seed as sold in the open market, analyse the samples thus taken, compare the results attained with the guaranties, and publish in full information as to their "character, value and use."

3. That the Station notify wholesalers and retailers of violation of the law, hold hearings and notify states' attorneys of the results of such hearings, with a view of prosecution "if in (the) judgment (of the state's attorney) the circumstances of the case warrant such action."¹

THE FARMER'S DUTIES

This enactment requires:

1. That the farmer do nothing whatsoever. He may buy the foulest seed that ever was harvested, if he wants to do so; and the law neither forbids his doing so nor shields him from his folly.

¹ A single hearing was held in 1914. Several lots of foul redtop were withdrawn from sale by dealers on notification by the Station. It was impractical during the past season to secure the analytical results in time to take effective measures along this line. Arrangements now have been perfected so that, beginning with the coming (1916) season, the analytical results will be secured more promptly than heretofore, and cases of misbranding and adulteration will be handled as rapidly as possible. The local seed trade, so far as possible, has been notified by letter that, beginning with the spring of 1916, the letter of the law will be followed in all cases brought to the attention of the Station of failure to guarantee, of sale of ergoted seed, or of seed materially inferior in purity to its guaranty. The wholesale trade has been similarly notified.

Common sense, however, requires :

1. That the farmer, when buying seed, take advantage of the protection afforded by the law.
2. That he note and be guided by the purity statement on the package.
3. That he note and be guided by the weed seed statement on the package.
4. That he insist on a guaranty in case a dealer attempts to sell him seed without the statement required by law.
5. That he study the annual seed inspection bulletins and compare wholesalers' promises and performances.
6. That he buy the better grades, which usually are likely to be the least costly not only in pure seed purchased but in the exclusion of weed seeds.

CONCERNING HIGH AND LOW GRADE SEED

This latter suggestion seems worth elaborating. The farmer who is buying seed should realize that a 100 percent purity statement on a seed package means "pure" seed, and that a 73 percent purity statement on a seed bag means that 27 percent of what he buys consists of weed seeds, dirt and other foreign material. He should try to grasp the idea that purchased dirt means lost money, lost for one year only, which is bad enough ; but that buying weeds at the price of good seed means not only lost money for one year but lost money at interest, at many times the legal rate, compounding at a usurious rate for long years to come in the shape of millions of weeds, a yearly loss which is quite equal probably to the taxes on the land they occupy. To pay taxes on land which grows mostly weeds, which were bought and paid for as timothy or clover or redtop, seems like adding insult to injury. Yet listers are inexorable and seed dealers offer cheap—but really costly—seed, full of weed seeds ; for some farmers demand it.

The law protects the buyer who exercises care in purchase. In a general way he can form a shrewd estimate of the amount of weed seed in a given lot of seed by even a cursory survey of the label which the law requires each seller to affix to his offerings. The following excerpt from the 1915 data of Vermont sales accurately displays the general relation existing between a high purity guaranty and a low weed seed content on the one hand and a relatively low purity guaranty and a high weed seed content on the other hand.

TABLE I—HIGH GRADE AND LOWER GRADES COMPARED

Seed	Guaranteed purity	Approximate weeds per pound
Alfalfa	99.7	180
Alfalfa	98	1820
Alsike clover	99.5	3325
Alsike clover	87	14228
Alsike clover	70	39925
Redtop	95	6810
Redtop	78	187502
Timothy	99.95	0
Timothy	99.8	0
Timothy	93	65700

He who buys a brand guaranteed in the high nineties usually is fairly safe, particularly if the station bulletin dealing with the previous year's trade indicates that the brand in question substantially maintained its guaranty statement. But the farmer who deliberately buys a seed carrying a low purity guaranty—and there are many such—cannot expect to get pure goods, any more than he who buys a suit of clothes at \$4.79 can expect to wear all wool garments. However, it should be remembered that the guaranty statement does not always indicate thus by indirection the weed seed or other foreign matter content of a sample; for the reason that sometimes the guaranty is overstated. For instance, a sample of redtop secured in the present inspection was guaranteed to be 99 percent pure. A farmer who contemplated buying this seed would be warranted in expecting it to be comparatively clean and free from weed seed. However, its analysis showed that only 75 percent of this seed actually was redtop and that it contained approximately a quarter of a million weed seeds in a pound, not to speak of a liberal supply of timothy. It contained 25 times as much impurity as it was said to contain. Common plantain, five finger, black-eyed susan, blue vervain, and yarrow were its main weed seed contents. It would be bad enough for a farmer to sow these weed seeds and to have to fight their progeny for years to come, but in addition, this redtop seed contained approximately 180 ergoted grains to the ounce and this fact was not proclaimed, as it should have been, on the package. This is 180 times as many as are permissible by the terms of the law. No one need be deceived by such a seed, however, for its inferior character can be detected readily by any person who will take the trouble to learn what a redtop seed looks like. And seed buyers who compare the wholesaler's promise and performance as shown in the bulletin are still further protected by the publication of the facts, if they take the pains to ascertain them.

The weed problem, like the poor, is always with us. If every farmer knew the seeds of our common grasses and clovers as well as he does those of oats, wheat and corn, there would be less weeds bought and paid for. It is not a difficult task to learn the appearance of these seeds. As for the weed seeds, it is only necessary to know that they are weed seeds. In most cases it matters but little what kind of weed seeds they are. The use of a common reading glass and the employment of a few minutes time may save the would-be buyer much future trouble.

What percentage of purity may be expected? The following table is proof of the statement that dealers are able to furnish seed of high percentages of purity. They are glad to do so, they prefer to do so as a rule, for such seed gives better satisfaction than does a low grade brand, and a satisfied customer is one's best advertisement.

TABLE II—SAMPLES OF RELATIVELY HIGH QUALITY—VERMONT INSPECTION, 1915

	Purity (official test)
Alfalfa	99.86
Alsike clover	99.58
Red clover	99.6
Corn	100
Millet	99.9
Redtop	97.5
Timothy	99.95
Sweet clover	99.45
White clover	98.56
Orchard grass	99.2

A farmer buying seed may get some notion, indeed a pretty clear notion, of what sort of seed is offered him by his dealer by noting the brand name and guaranty and then looking up the quality record of the brand as found on sale during the preceding year.

Unfortunately in the seed trade, as in feed and fertilizer trade, many wholesalers feel that they must meet the demands of those farmers who insist on buying only the lowest grades, on getting the most possible for a dollar regardless of quality. The law does not protect such a man against the consequences of his own unwisdom, the results of which may affect others as well as himself; for he who buys weedy seed endangers his more thrifty neighbors, whereas the man who buys a low grade fertilizer or a cheap feed damages only himself. Such being the case, it may be well to consider whether more drastic provisions might not be engrafted to advantage on the Vermont enactment, with a view of excluding the lower grades from our markets. Canadian laws prevent the sales of low grades; and they are shipped over the line for us to buy. We keep out undesirable human immigration.

federal officers being stationed at Alburg, St. Albans, Richford, Newport and Beecher Falls for this purpose. Would it not be well to keep out undesirable plant immigrants; and, also, to make it less likely that our already large weed family be increased by further importation from our sister states?

DISCUSSION OF THE RESULTS OF INSPECTION

A study of tables VI-XIII and especially of table XIV, pages 17 to 39 shows that many wholesalers furnish seed which is better than their guaranties and that their goods seldom fail to be as good as they are said to be. Speaking broadly, it appears that the guaranties of these houses can be taken without question at face value. It is a matter of regret that, if one is to judge by the results secured in the Vermont inspections of 1914 and 1915, this statement cannot be extended to cover the offerings of all wholesalers. The final remedy for this state of affairs does not lie in the application of the penal section of the law; as already has been set forth, the seed-buying public should inform itself by a study as to the facts.

The results of the laboratory tests show wide variations in the quality of the seed offered in Vermont markets during the past spring. Some brands were especially weedy. A glance at the last column in the tables VI to XIV, pages 17 to 39, shows the great variation in this respect. The law does not require the dealer to state the weed-seed content on his label, but the consumer doubtless would be glad to see the law so extended as to include this information, an extension which probably would be opposed strongly; but not by seed users.

The Federal Department of Agriculture has compiled data in an attempt to establish a standard of purity and germination of agricultural seed. This represents what reasonably may be expected in commercial seed.

TABLE III—STANDARDS OF PURITY AND GERMINATION OF AGRICULTURAL SEEDS

Seed	Germination		Seed	Germination	
	Purity %	%		Purity %	%
Alfalfa	98	85-90	Melon	99	85-90
Asparagus	99	80-85	Millets	99	85-90
Barley	99	90-95	Mustard	99	90-95
Bean	99	90-95	Oats	99	90-95
Blue grass, Canadian..	90	45-50	Okra	99	80-85
Blue grass, Kentucky..	90	45-50	Onion	99	80-85
Brome, awnless	90	75-80	Parsley	99	70-75
Buckwheat	99	90-95	Parsnip	95	70-75
Cabbage	99	90-95	Peas	99	93-98
Carrot	95	80-85	Pumpkin	99	85-90
Cauliflower	99	80-85	Radish	99	90-95
Celery	98	60-65	Rape	99	90-95
Clover, alsike	95	75-80	Redtop	95	75-80
Clover, crimson	98	85-90	Rye	99	90-95
Clover, red	98	85-90	Salsify	98	75-80
Clover, white	95	75-80	Sorghum	98	85-90
Collard	99	90-95	Spinach	99	80-95
Corn, field	99	90-95	Spurry	99	85-90
Corn, sweet	99	85-90	Squash	99	85-90
Cowpeas	99	85-90	Timothy	98	85-90
Cucumber	99	85-90	Tomato	98	85-90
Eggplant	99	75-80	Turnip	99	90-95
Fescue, meadow	95	85-90	Tobacco	98	75-80
Lettuce	99	85-90	Wheat	99	90-95
Kafir corn	98	85-90			

Some of the seed sold in Vermont in 1915 were better than the so-called federal standard as to purity and some were not, as appears in the following statement.

TABLE IV—COMPARISON WITH FEDERAL STANDARD AS TO PURITY

	Total number tested	Above United States standard as to purity	Below United States standard as to purity
Alfalfa	9	9	0
Alsike clover	46	27	19
Red clover	57	40	17
Corn	85	43	42
Millet	38	13	25
Redtop	16	3	13
Timothy	53	50	3
Miscellaneous seed			
Barley	12	2	10
Blue grass	3	3	0
Buckwheat	2	2	0
White clover	4	2	2
Oats	6	6	0
Peas	3	2	1
Rape	1	0	1
Rye	1	1	0
Wheat	1	1	0
	337	204	133

This showing is none too good; 60 percent being equal to or better than standard, and 40 percent below standard as regards purity. It

should be understood, however, that these so-called standards have no legal status; that the law establishes no grades; that the dealer may sell the foulest of seed without being in any way amenable to the law, provided that upon each lot of five or more pounds he sets forth clearly and accurately the nature and extent of its foulness. It is for the buyer to keep his eyes open. The law does not protect him if he is cheated in a horse trade, if he buys a spavined animal thinking it is sound. It does protect him in seed purchase, if he reads the statements on the package.

VIOLATIONS OF THE LAW

The chief violations in 1915 were:

- (1) Failure to furnish the guaranty required by law.
- (2) Failure substantially to maintain guaranties.
- (3) The sale of ergoted grains.

1. *The omission of a guaranty seems inexcusable*, now that the law has been in force for some time; and, beginning with 1916, errors of omission so far as they come to the attention of the Station will be dealt with in accordance with the provisions of the law. It is only just to say in this connection, however, that in several cases there seems reason to believe that guaranties were as a matter of fact furnished by the wholesalers in the form of tags which were either lost in transit or destroyed by the retailer, who failed to appreciate what he was doing and in what an unfavorable light he was placing both himself and the party from whom he bought his supplies. Failures to guaranty, therefore, are not always, or usually, to be charged against the wholesaler.

2. *The divergencies between guaranteed purity and actual purity* found on analysis often were very small, and may be explained by sample variation or analytical variation; that is to say, the margin of error necessarily incident to the operations of sampling and analysis might well be considered to cover the divergency between promise and performance. No note should be taken of these cases; indeed the very terms of the law cover such occurrences and its phraseology was shaped designedly with this point in view when it was made to read—"provided that no penalty or liability shall be applicable to a seller of seeds in relation to the quality thereof, if the same is found to be substantially equivalent to the guaranty." In several cases, however, the discrepancy between guaranty and analysis seems too wide to be thus explained.

3. *The sale of ergoted grains* is perhaps in a measure excusable in view of the fact that, while a desirable feature of the Vermont law, for no one wants to grow ergoted grain, it is not prohibited by the laws of several states from some of which a considerable share of Vermont seed supplies are derived. It is likely to occur only in timothy and redtop. Lots which have been found to be infested seriously in the past have been withdrawn from sale and arrangements now are perfected so that, beginning with the coming spring, early steps will be taken to secure either withdrawal from sale or proper labelling preceding sale of all lots which upon analysis prove to carry ergot.

The following tabular statement should prove of service to buyers of seed. It concisely sets forth the situation as regards compliance with the law by the several purveyors of seed, 343 samples of whose goods were taken in the spring of 1915, in so far as it relates to:

1. The presence or absence of the guaranty statement.
2. The failure to furnish substantially the proportion of pure seed which is guaranteed.

3. The failure to declare the presence of ergotized seed.

An examination of the results given in table V shows:

1. That approximately six-sevenths of the lots were guaranteed and that one-seventh was unguaranteed.
2. That ninety-five percent of the guaranteed samples were substantially as pure as they were said to be.
3. That seven lots each of timothy and of redtop contained ergotized grains and one lot of wheat contained corn cockle; whereas in only a single case was the presence of these adulterations declared on the package.

The wholesalers in several cases claim that the goods represented to be unguaranteed as a matter of fact were guaranteed. It is of course possible that in some cases the sampling agents overlooked the guaranties; but in view of the fact that at the time when they were employed in seed sampling they were engaged likewise in sampling commercial fertilizers and feeding stuffs, commodities which are required to carry guaranties and much more complicated guaranties than those employed in the seed trade, and that without a single exception they recorded and filed in their reports fertilizer and feeding stuff guarantees; and further in view of the fact that in the initial years of the operation of the fertilizer and feeding stuff laws it was common for wholesalers through oversight to omit guarantees, a history which it is notorious is being repeated in connection with the inauguration of the new seed

TABLE V—OBSERVANCE OF THE LAW

Name and address of wholesaler	Number of samples	Number guaranteed ¹	Guaranties sub- stantially made good	Guaranties more than 2 percent high of analysis	Ergot present, but not declared
Bailey & Co., E. W., Montpelier, Vt.....	15	12	9	3	1*
Barber & Bennett, Albany, N. Y.....	9	9	9	..	..
Breck & Sons Corporation, Jos., Boston, Mass.	14	9	8	1	..
Champlain Seed Co., Burlington, Vt.....	4	4	2	2	..
Conklin & Son, E. W., Binghamton, N. Y....	26	26	25	1	..
Dickinson Co., Albert, Chicago, Ill.....	43	42	40	2	3‡
Craver-Dickinson Seed Co., Binghamton, N. Y.	2	1	1	..	..
Emerson, Thos. W., Boston, Mass.....	5	1	1	..	..
Griswold & Mackinnon, St. Johnsbury, Vt....	4	3	3	..	1†
Half Century Store Co., Randolph, Vt.....	1	1	1	..	..
Holbrook Grocery Co., Keene, N. H.....	45	40	39	1	3*
Illinois Seed Co., Chicago, Ill.....	1	..	..	..	..
Johnson & Co., W. B., Essex Junction, Vt....	1	1	1	..	..
Landon & Co., W. C., Rutland, Vt.....	4	3	3	..	..
McEwen Milling Co., R. H., Ogdensburg, N. Y.	1	..	..	..	..
Michigan Seed Co., Burlington, Vt.....	2	0	..	..	..
Middlebrook & Sons, J. O., Burlington, Vt..	4	4	4	..	..
Morehouse & Co., W. H., Toledo, Ohio.....	16	14	13	1	1†
Page Seed Co., Greene, N. Y.....	11	5	5	..	..
Pine Tree Seed Co.,	1	1	1	..	1†
Rice Seed Co., J. B., Cambridge, N. Y.....	10	3	3	..	..
Ross Bros. Co., Worcester, Mass.....	1	..	..	..	..
Scarlett & Co., Wm. G., Baltimore, Md.....	4	4	4	..	..
Small & Co., W. H., Evansville, Ind.....	15	10	7	3	2†
Spaulding & Kimball Co., Burlington, Vt....	3	3	3	..	..
Sanford Seed Co., Buffalo, N. Y.....	69	65	65	..	1†
Teweles Seed Co., L., Milwaukee, Wis.....	1	1	1	..	..
Varick Co., John B., Manchester, N. H.....	2	2	2	..	..
Whitney-Eckstein Seed Co., Buffalo, N. Y....	28	19	19	..	1†
Woodruff, F. H., Milford, Conn.....	1	..	..	..	..
Totals	343	283	269	14	14

*Redtop. †Timothy. ‡Corn cockle. §Two Redtop, one timothy.

¹ A lack of guaranty statement is not necessarily or usually the fault of the wholesaler but of the retail merchant.

enactment, it seems safe to conclude that in most cases the sampling agent's report of "no guaranty statement" accurately represents the situation at the point at which the sample was drawn. Furthermore it is not unlikely that in several cases the guarantees were as a matter of fact furnished by the wholesalers in the form of tags affixed to the bags and that the retailers removed them; a violation of the law in that goods thus exposed for sale did not bear a guaranty statement. It may have been, however, that in some, perhaps in all cases, actual sales of five pounds or more were as a matter of fact properly guaranteed. In short, the nature of the seed trade is such that it is not as easy for

the Station to assert dogmatically in a given case that the intent of the law has been defeated as it is in the case of a similar lapse in connection with the fertilizer or feeding stuff laws.

The attitude of one wholesaler is quite unlike that of the trade in general. He insists that such guaranties as were found to be attached to the stock from his seed house and offered for sale in Vermont, be omitted. He states that he makes no guaranties of any sort and that any such made by the retailer should not be published by the Station in connection with his name. This is an interesting point of view, particularly to the several retailers throughout the State who buy from this house, who, if they comply with the law, must each submit samples to some competent authority for analysis as to purity or otherwise secure the data. However, it has no bearing so far as the Station is concerned. The goods were found by its sampling agents offered for sale in Vermont carrying a definite guaranty as required by law; and the law requires the publication of the names and addresses of the wholesalers of the seed together with the results of the tests.

In some cases the authenticity of samples and the accuracy of analyses are questioned. The instructions given the sampling agents to take but one sample at a time, and to finish labelling one before beginning to take another sample, would seem reasonably well to safeguard the authenticity of the sample in so far as the Station is able to do so. The essential accuracy of the analyses of all samples listed as not substantially equalling the printed guaranty statement made in their behalf, or as containing ergoted seed, was determined by repeated trials. Sub-samples of these lots were submitted to the wholesalers on request, but no analyses as made and verified by our own analysts were quashed, the seller's results to the contrary notwithstanding. The Station affirms belief in the essential accuracy of all the analytical findings repeated in this bulletin, assuming the authenticity of the original samples. However, it seems only right to give publicity to the following protests of wholesalers.

Jos. Breck & Sons Corporation state concerning the unnamed redtop guaranteed 90 percent pure, found 85.5 percent pure, that "foreign matter in some way must have gotten into this seed after it left our place of business" and questions the method of sampling. Of course the Station cannot state whether or not the material found on sale in Vermont represents what was furnished by the wholesalers. It can only say that the sample—and all samples—were drawn in standard fashion and that the analysis correctly represents the sample.

Holbrook Grocery Co. was unaware of the ergot clause in the Vermont law, but will be guided thereby hereafter.

Illinois Seed Co. claim that they made proper guaranty and that either the local dealer or the sampling agent were at fault. The former states that he knows of no guaranty statement on the packages; the latter found none. Of course a guaranty may have been made in good faith in the form of a tag which was lost or destroyed.

W. H. Morehouse & Co. believe that in certain cases their shipments are actually better than the samples would indicate.

Stanford Seed Co. states that guaranties were furnished in all cases and that omissions represent loss or removal of tags after the goods left their hands.

Whitney-Eckstein Co. was unaware of the ergot clause in the Vermont law, but will be guided thereby hereafter.

Several retailers stated that they "knew nothing of the law"; that they "supposed the seed was all right"; that they had "inadvertently removed the tags," etc. Some claim vaguely "some mistake." A few specifically deny the accuracy of the alleged facts, one asserting vigorously that he had strictly complied with the law and marked each five-pound package. A considerable number made no answer to the Station's letters, evidently believing that "silence is golden."

In the following cases divergence between promise and fulfillment is excessive.

<i>E. W. Bailey & Co., Montpelier, Vt.</i>		
Alsike clover; Ace brand.....	guaranteed 98.7	found 94.8
Redtop; unnamed	guaranteed 99	found 75
<i>Jos. Breck & Son, Boston, Mass.</i>		
Redtop; no name	guaranteed 90	found 85.5
<i>Holbrook Grocery Co., Keene, N. H.</i>		
Redtop; X	guaranteed 90	found 85
<i>W. H. Small & Co., Evansville, Ind.</i>		
Alsike clover; no name	guaranteed 98.5	found 94.03
Redtop; no name	guaranteed 92	found 53.5

UNDERGUARANTEEING

A somewhat absurd situation has developed in the working of the seed law. A great many small dealers in seed corn, seed oats, etc. sell locally seed of their own growth. In order to comply with the law, some of these men are guaranteeing, for example, seed corn 50 percent pure; seed oats, 20 percent pure, on the ground that the law does not forbid understatements and that such statements allow a sufficient margin of safety. A somewhat similar situation was met in the early days of the enforcement of the feeding stuff laws, when

certain feed dealers guaranteed their goods to contain one percent of crude protein. This state of affairs doubtless will become self-corrected in due time.

THE 1916 SEED SITUATION

There seems to be unusual shortage this year in certain lines of field and garden seeds. European supplies of course are curtailed and untoward climatic conditions occurred during the 1915 season of seed maturing in certain sections. Higher prices will be asked for certain sorts of seed than have obtained of late years and there seems likelihood that supplies will be insufficient to meet the normal demand of some seed, even at greatly advanced prices. It behooves farmers to be forehanded in this matter and buy promptly. The supplies of alfalfa, vetch and white clover seed are said to be very inadequate, of medium clover and timothy to be somewhat short, whereas redtop and blue grass seed supplies are normal. The quality of much of the 1915 seed oats and corn is said to be inferior, owing to persistent rains at harvest time. On this account there seems more than usual need of care in purchase and of making home germination trials.

"LEST WE FORGET"

The farmer who buys seed should:

1. Buy only guaranteed seed.
2. Look for and interpret the guaranty.
3. Do a sum in subtraction as follows:
 $100 - \text{guaranty} = \text{weed seeds, dirt, etc.}$
4. Examine timothy, and especially redtop, for ergoted grains.
5. Learn to recognize the appearance of the seeds of the common grains and clovers.

RESULTS OF ANALYSES

TABLE VI—ALFALFA

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound
IXL	E. G. & A. W. Norton, Vergennes..	Conklin	99.29	97.25	91
Pine Tree	Field & Lawrence, Bellows Falls..	A. Dickinson....	99.7	99.5	None
Ace	Burditt Bros., Rutland..	A. Dickinson....	99.02	99.3	546
Anchor	J. W. Jones & Co., Burlington..	Morehouse	99.5	None	454
Bulked Fancy..	S. P. Curtis & Son, Rutland..	Stanford	99.3	99.52	None
Empire	A. H. Winslow, Bennington..	Stanford	99.86	99.5	180
Fancy	Geo. H. Pelky, St. Albans..	Small	99	98	1820
Eclipse	Burlington Flour Co., Burlington..	Whitney-Eckstein	99.62	99.7	180
No name					

¹ For explanation of abbreviations of wholesalers' names see page 40.

TABLE VII—ALSIKE CLOVER

Ace	R. C. Clark, Barre..	Bailey	94.68	93.7	7120
Ace	Arch. Batchelder, Plainfield..	Bailey	94.8	98.7	7381
Ace	E. W. Bailey & Co., Montpelier..	Bailey	98.8	99.5	3375
Prime	LaFountain & Woolson, Springfield..	Breck	92.5	....	7254
C. M.	E. M. Bixby & Son, Poultney..	Conklin	95.2	95.45	2497
C. M.	E. G. & A. W. Norton, Vergennes..	Conklin	94	95	7718
C.	A. D. Pease, Burlington..	Conklin	91.7	87.65	19206
Pine Tree	Hatch Hardware Co., St. Albans..	A. Dickinson....	98.65	98	1080
Globe	Hatch Hardware Co., St. Albans..	A. Dickinson....	99.25	97	910
Ace	A. H. McLeod Mill. Co., St. Johnsbury..	A. Dickinson....	92.8	93.7	9761
Ace	Field & Lawrence, Bellows Falls..	A. Dickinson....	93.5	95	9988
Queen	A. H. McLeod Mill. Co., St. Johnsbury..	A. Dickinson....	86.5	87	14528
Kaiser	H. O. Holt & Co., Richford..	A. Dickinson....	90.44	87.8	18400
Kaiser	A. H. McLeod Mill. Co., St. Johnsbury..	A. Dickinson....	92.25	91	18614

TABLE VII —ALSIKE CLOVER—Cont.

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound
Kaiser	Burditt Bros., Rutland..	A. Dickinson....	91.7	92	15890
Pine Tree	E. W. Bixby & Son, Poultney..	Craver-Dickinson	96.75	....	3632
Ace	Geo. Stannard, Fair Haven..	Craver-Dickinson	94.75	96.3	18841
XX	George Shorey, Lyndonville..	Holbrook	81.08	78	32625
X	F. M. Kempton, Barre..	Holbrook	69.54	70	39925
Globe	W. B. Ladd, Enosburg Falls..	Holbrook	98.75	99	450
XXX	Twombly & Colton, Orleans..	Holbrook	93.74	90	8775
White Mt.	Clark & Davison, Groton..	Holbrook	99.5	98	454
Blue Jay	M. P. Perley & Co., Enosburg Falls..	Morehouse	99.25	98.5	675
Bell	M. P. Perley & Co., Enosburg Falls..	Morehouse	97.47	97	671
Anchor	J. W. Jones & Co., Burlington..	Morehouse	99.58	99.5	444
Oak	H. F. Estabrook, St. Johnsbury..	Scarlett	98.76	96	8379
Queen	C. F. Stevens, Randolph..	Spau'g & Kimball	86.75	87.5	9988
Eclipse	Story & Barkyounb, St. Albans..	Small	94.75	97.5	7650
.....	Griswold & Mackinnon, St. Johnsbury..	Small	94.03	98.5	9460
Arc	Cunningham & Jennings, St. Albans..	Stanford	98.57	97.5	None
Arc	Mathews & Hall, Orleans..	Stanford	98.1	96.8	4000
Reliable	Geo. H. Pelky, St. Albans..	Stanford	98.57	97.50	220
Arc.....	D. H. McHugh, Middlebury..	Stanford	99.2	98	225
Arc.....	E. I. Benson, Woodstock..	Stanford	96.3	95.8	1260
.....	Hardwick Hardware Co., Hardwick..	Stanford	98.84	98.8	None
W.	H. P. Munson, Morrisville..	Stanford	96.57	96	1776
Honor	A. H. Winslow, Bennington..	Stanford	99.4	97	None
Honor	F. M. Sherman Co., Newport..	Stanford	98.61	98.75	450
Fancy	Twombly & Colton, Orleans..	Stanford	97.64	96.75	3960
Fancy	J. G. Turnbull Co., Orleans..	Stanford	97.88	96.8	2700

TABLE VII—ALSIKE CLOVER—Cont.

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound
Fancy	C. E. Miller, Wells River..	Whitney-Eckstein	97.95	97	5580
Export Fancy....	Cunningham & Jennings, St. Albans..	Whitney-Eckstein	98.74	98	764
Frontier	Harris & Co., Morrisville..	Whitney-Eckstein	92.82	85	3016
Pan-American ...	Mathews & Hall, Orleans..	Whitney-Eckstein	99.31	97	450
Pan-American ...	H. G. Folsom Co., St. Albans..	Whitney-Eckstein	96.74	97	2968
Eureka	Combination Cash Store, Manchester..	Whitney-Eckstein	99.5	98.5	454

TABLE VIII—RED CLOVER

Ace	C. P. Abbott, South Royalton..	Bailey	98.86	98.5	4050
.....	Richmond & Son, Northfield..	Bailey	98.81	98	2970
AA Medium	A. H. Winslow, Bennington..	Barber & Bennett	98.96	99	1080
A Medium	A. H. Winslow, Bennington..	Barber & Bennett	99.1	98.9	630
Ace	Half Century Store, Randolph..	Breck	99.22	98	900
Prime	LaFountain & Woolson, Springfield..	Breck	98.4	99.35	2160
.....	LaFountain & Woolson, Springfield..	Breck	98.5	96	2250
Atlas Medium ...	Geo. Stannard, Fair Haven..	Conklin	98.6	97.25	1365
Paragon Medium..	E. W. Bixby & Son, Poultney..	Conklin	98.8	98.25	819
Crown Medium ...	E. G. & A. W. Norton, Vergennes..	Conklin	99.52	99.25	1183
Crown Mammoth..	E. G. & A. W. Norton, Vergennes..	Conklin	99.5	99.25	728
Etna Mammoth..	Combination Cash Store, Manchester..	Conklin	92	93.7	9191
Atlas Mammoth..	F. W. Barrett, Poultney..	Conklin	98.5	97.2	1638
Pine Tree	Hatch Hardware Co., St. Albans..	A. Dickinson....	99.26	98	3825
Pine Tree	E. J. Davis, Chester..	A. Dickinson....	98.9	99	910
Globe	Field & Lawrence, Bellows Falls..	A. Dickinson....	99.24	99.6	1092
Globe	Hatch Hardware Co., St. Albans..	A. Dickinson....	99.25	99	90
Kaiser	A. H. McLeod Mill. Co., St. Johnsbury..	A. Dickinson....	96.7	97	7189

TABLE VIII—RED CLOVER—Cont.

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound
Queen	A. H. McLeod Mill. Co., St. Johnsbury..	A. Dickinson....	91.6	91.4	10192
Queen	J. H. Carr, Hardwick..	A. Dickinson....	97	96	3822
Mammoth	Hatch Hardware Co., St. Albans..	A. Dickinson....	98.5	98.4	2550
Ace	A. H. McLeod Mill. Co., St. Johnsbury..	A. Dickinson....	98.18	96	3185
Ace	E. J. Davis, Chester..	A. Dickinson....	98.3	98	1729
Ace	H. O. Holt & Co., Richford..	A. Dickinson....	99.3	99.7	364
Ace	W. C. Landon & Co., Rutland..	Holbrook	99.2	98	540
Ace	W. C. Landon & Co., Rutland..	Holbrook	98.2	96.8	330
Queen	W. C. Landon & Co., Rutland..	Holbrook	98.2	96	3600
White Mountain..	S. E. Clark, Wells River..	Holbrook	99.2	99.5	90
Globe	W. B. Ladd, Enosburg Falls..	Holbrook	99.3	99	500
XXX	Twombly & Colton, Orleans..	Holbrook	97.32	96.5	4929
Monadnock	Howard Hardware Co., Bellows Falls..	Holbrook	99.4	99	540
XX	C. McFarland & Son, Barton..	Holbrook	92.35	90	10962
.....	Madden & Trumbull, White River Jct..	Holbrook	94.2	90	2700
.....	E. Lane & Son, Newport..	Holbrook	91.44	80	24800
.....	F. M. Kempton, Barre..	Holbrook	91.65	80	33300
Anchor	M. P. Perley & Co., Enosburg Falls..	Morehouse	99.48	....	180
Bell Toledo	M. P. Perley & Co., Enosburg Falls..	Morehouse	99.4	99.5	900
Oak	H. F. Eastabrook, St. Johnsbury..	Scarlett	98.81	97.2	3116
Old Style Fancy..	E. Lane & Son, Newport..	Small	89.86	....	23205
Queen	S. F. Stevens, Randolph..	Spau'g & Kimball	94.34	94.8	4263
Climax Superfine.	Story & Barkyoumb, St. Albans..	Small	98.38	99.04	7200
Eclipse	E. Lane & Son, Newport..	Small	91.97	....	20995
Honor Brand Medium	Clark & Davison, Groton..	Stanford	99.28	99.25	1800
Choice Medium ..	Twombly & Colton, Orleans..	Stanford	97.06	94	15000

TABLE VIII—RED CLOVER—Cont.

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound
Arc Medium.....	Mathews & Hall, Orleans..	Stanford	99.24	99.2	1800
Arc Medium.....	W. H. Adams, Vergennes..	Stanford	99	99	1400
Arc Mammoth ...	S. P. Curtis & Son, Rutland..	Stanford	99.53	99	1400
Arc Mammoth ...	J. W. Gillis, Danville..	Stanford	99.6	98.5	1000
Arc.....	E. I. Benson, Woodstock..	Stanford	99.43	99.25	450
Ace	S. A. Reed, Windsor..	Varick	99.66	98	625
Pan-American ...	G. A. Hathaway, North Bennington..	Whitney-Eckstein	98.66	....	2282
Pan-American ...	Combination Cash Store, Manchester..	Whitney-Eckstein	96.68	....	4472
Medium	L. E. Avery & Son, Vergennes..	Whitney-Eckstein	97.43	98	6035
Mammoth	L. E. Avery & Son, Vergennes..	Whitney-Eckstein	98.06	98	4200
Herald	C. A. Leland, Springfield..	Whitney-Eckstein	98.46	97	4576
Frontier	Harris & Co., Morrisville..	Whitney-Eckstein	94.12	92	7380
Eureka	C. E. Miller, Wells River..	Whitney-Eckstein	99.56	99	900

TABLE IX—CORN

Improved Leaming	Cunningham & Jennings, St. Albans..	Bailey	99.69	90	....
Early Mastodon..	Mathews & Hall, Orleans..	Bailey	100	....	....
Sanford White Flint Field	Mathews & Hall, Orleans..	Bailey	98.12	....	....
Sanford White ..	C. F. Stevens, Randolph..	Bailey	98.92	99.6	....
Longfellow	C. F. Stevens, Randolph..	Bailey	99.7	99.5	....
Eureka	MacDiarmid & Co., Newport..	Bailey	99.25	99.5	....
Perry's Hybrid ..	M. P. Perley & Son, Enosburg Falls..	Breck	99.47	....	....
Early Mastodon..	M. P. Perley & Son, Enosburg Falls..	Breck	99.51	....	....
Longfellow Flint ..	J. W. Jones & Co., Burlington..	Breck	99.35	99	....
Sanford Flint ...	J. W. Jones & Co., Burlington..	Breck	98.53	99	....
Burlington Dent..	D. H. McHugh, Middlebury..	Champlain	96.46	99.95	....

TABLE IX—CORN—Cont.

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound
Northern Sanford	C. H. Robinson,	Brandon..Champlain	96.36	99.95	....
.....	Cunningham & Jennings,	St. Albans..Champlain	100	99.95	....
Pride of Nashua..	W. H. Adams,	Vergennes..Champlain	99.6	99.95	....
Imperial Leaming	F. W. Barrett,	Poultney..Conklin	98.5	99	....
Imperial Leaming	F. W. Barrett,	Poultney..Conklin	99.66	99.22	....
White Sanford...	F. W. Barrett,	Poultney..Conklin	98.78	98.28	....
Sanford Flint....	W. B. Ladd,	Enosburg Falls..A. Dickinson....	99.24	99	....
Sanford	J. C. Eaton,	Lyndonville..Emerson	98.62	....	....
Longfellow Yellow Dent...	H. O. Holt & Co.,	Richford..Emerson	98.31	....	....
Eureka	H. O. Holt & Co.,	Richford..Emerson	99.61	....	....
Sanford	Griswold & Mackinnon,	St. Johnsbury..Griswold & Mack.	99.22	99	....
Leaming	C. McFarland & Son,	Barton..Holbrook	98.89	99	....
E. C. F.	C. McFarland & Son,	Barton..Holbrook	98.39	99	....
Gold Nugget	W. B. Ladd,	Enosburg Falls..Michigan	98.34	....	....
Vermont Dent ...	J. G. Turnbull Co.,	Orleans..Michigan	99.31	....	....
Sanford Flint....	J. O. Middlebrook & Sons,	Burlington..Middlebrook	100	95	....
Improved Leaming	J. O. Middlebrook & Sons,	Burlington..Middlebrook	99.69	95	....
Early Mastodon..	J. O. Middlebrook & Sons,	Burlington..Middlebrook	98.77	95	....
King of Earliest..	J. O. Middlebrook & Sons,	Burlington..Middlebrook	99.91	95	....
Michigan Golden Dent	M. P. Perley & Co.,	Enosburg Falls..Morehouse	99.17	99.5	....
Eureka White Corn	M. P. Perley & Co.,	Enosburg Falls..Morehouse	98.11	99.5	....
Longfellow Yellow Flint...	J. W. Jones & Co.,	Burlington..Morehouse	98.91	99.5	....
Stowell's Evergreen	J. W. Jones & Co.,	Burlington..Morehouse	99.21	99	....
Southern White..	J. W. Jones & Co.,	Burlington..Morehouse	98.85	99.5	....
Leaming	J. W. Jones & Co.,	Burlington..Morehouse	99.91	99.5	....
Pride of the North	Howard Pruden,	Poultney..Page	98.71	....	....
Page's Genesee Valley Flint ...	D. H. McHugh,	Middlebury..Page	98.10	90	....

TABLE IX—CORN—Cont.

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound
Golden Nugget...	A. H. McIntyre,	Brandon..Page	97.46	....	....
Eureka	A. H. McIntyre,	Brandon..Page	100	....	....
Leaming	S. S. Sherman & Son,	Poultney..Page	98.36	....	....
Leaming	E. G. & A. W. Norton,	Vergennes..Page	98.36	90	....
Page's High Bred Eureka...	E. G. & A. W. Norton,	Vergennes..Page	99.58	90	....
Page's Early Triumph	E. G. & A. W. Norton,	Vergennes..Page	99.05	90	....
Stowell's Evergreen	E. G. & A. W. Norton,	Vergennes..Page	99.57	90	....
.....	S. S. Sherman & Son,	Poultney..Page	100	....	....
Longfellow	S. S. Sherman & Son,	Poultney..Page	98.76	....	....
Sanford	C. A. Leland,	Springfield..Rice	96.12	....	....
Leaming	C. A. Leland,	Springfield..Rice	98.3	....	....
Eureka	LaFountain & Woolson,	Springfield..Rice	97.54	90	....
Eureka	E. H. Button,	Brandon..Rice	95.16	....	....
Eight-Rowed Canada	C. H. Robinson,	Brandon..Rice	99.98	....	....
Triumph Field	LaFountain & Woolson,	Springfield..Rice	98.75	90	....
Early Mastodon..	Combination Cash Store,	Manchester..Rice	98.32	....	....
100 Day	W. C. Landon & Co.,	Rutland..Rice	98.3	....	....
Golden Dent...	W. C. Landon & Co.,	Rutland..Rice	98.6	....	....
Pride of the North	LaFountain & Woolson,	Springfield..Rice	99.4	90	....
Early Northern Flint	W. C. Landon & Co.,	Rutland..Ross	99.34	....	....
Eureka	C. McFarland & Son,	Barton..Stanford	98.14	90	....
Improved Early Canada Flint..	E. G. & A. W. Norton,	Vergennes..Stanford	99.61	90	....
Improved Flint Longfellow	L. E. Avery & Son,	Vergennes..Stanford	97.36	90	....
Field Corn	E. G. & A. W. Norton,	Vergennes..Stanford	98.97	90	....
Improved Early Triumph	W. B. Johnson & Son,	Essex Junction..Stanford	99.71	90	....
Golden Dent	S. P. Curtis & Son,	Rutland..Stanford	99.66	95	....
Improved Stow-ell's Evergreen.					
Improved Stow-ell's Evergreen.					

TABLE IX—CORN—Cont.

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound
Eureka	S. P. Curtis & Son, Rutland..	Stanford	99.97	95	....
Eureka	R. P. Webster, Barton..	Stanford	97.8	....	....
Eureka	C. McFarland & Son, Barton..	Stanford	99.67	90	....
Golden Nugget ..	W. J. Gillis, Danville..	Stanford	99.7	90	....
Golden Nugget ..	Mathews & Hall, Orleans..	Stanford	98.12	90	....
Longfellow Flint.	E. M. Bixby & Co., Poultney..	Stanford	98.8	95	....
Longfellow Flint.	A. B. Taylor, Manchester..	Stanford	97.66	90	....
Improved Leaming	W. H. Adams, Vergennes..	Stanford	97.5	90	....
Improved Leaming	A. C. Calhoun & Son, Middlebury..	Stanford	99.65	90	....
Pride of the North	E. M. Bixby & Son, Poultney..	Stanford	99.15	95	....
Golden Harvest ..	W. H. Adams, Vergennes..	Stanford	98.07	90	....
Improved Sanford Flint..	W. H. Adams, Vergennes..	Stanford	99.55	90	....
Leaming	W. H. Adams, Vergennes..	Stanford	98.91	90	....
Early Triumph....	E. M. Bixby & Son, Poultney..	Stanford	99.4	95	....
Sanford Flint....	E. M. Bixby & Son, Poultney..	Stanford	100	95	....
Sanford Flint....	A. B. Taylor, Manchester..	Stanford	97	90	....
Sanford	D. H. McHugh, Middlebury..	Stanford	99.04	90	....
Sanford	S. P. Curtis & Son, Rutland..	Stanford	100	95	....
100 Day Dent....	Cunningham & Jennings, St. Albans..	Stanford	99.85	90	....
Evergreen Sweet Fodder..	Story & Barkyoumb, St. Albans..	Tewesles	99.35	100	....
Sanford White ..	A. H. Winslow, Bennington..	Woodruff	97.05	....	....

TABLE X—MILLET

Japanese	J. W. Jones & Co., Burlington..	Breck	98.11	96.8	4081
Japanese	LaFountain & Woolson, Springfield..	Breck	99.4	....	450
Japanese	Geo. H. Pelky, St. Albans..	Breck	98.47	....	3850

TABLE X—MILLET—Cont.

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound
Japanese	E. M. Bixby & Son, Poultney..Conklin	98.8	96.4	1638	
German	E. M. Bixby & Son, Poultney..Conklin	99.75	99.4	91	
German, Prime ..	E. G. & A. W. Norton, Vergennes..Conklin	95.8	98.6	1220	
Choice	E. G. & A. W. Norton, Vergennes..Conklin	97.4	99	7462	
Hungarian	E. M. Bixby & Son, Poultney..Conklin	97.8	99.2	6916	
Hungarian	Field & Lawrence, Bellows Falls..A. Dickinson....	98	97	3640	
Hungarian	H. A. Slayton & Co., Morrisville..A. Dickinson....	95.6	98	2366	
Hungarian	E. J. Davis, Chester..A. Dickinson....	99.8	98.3	273	
Japanese	H. A. Slayton & Co., Morrisville..A. Dickinson....	98.5	99	1000	
Japanese	Field & Lawrence, Bellows Falls..A. Dickinson....	99.6	98	273	
Japanese	E. J. Davis, Chester..A. Dickinson....	98.5	95	2639	
Japanese	J. O. Middlebrook & Sons, Burlington..A. Dickinson....	98.64	95.5	2541	
Japanese	Geo. Shorey, Lyndonville..Emerson	97.18	....	11305	
German	Howard Hardware Co., Bellows Falls..Holbrook	99.4	97.5	None	
German	W. C. Landon & Co., Rutland..Holbrook	97.2	96	None	
Japanese	J. H. Carr, Hardwick..Holbrook	95.5	90	11250	
Monadnock	Howard Hardware Co., Bellows Falls..Holbrook	98.6	97	2880	
Monadnock	Howard Hardware Co., Bellows Falls..Holbrook	99.6	98	1890	
XX Hungarian ..	Adams & Davis, Chester..Holbrook	99.5	97	810	
X Hungarian ...	J. H. Carr, Hardwick..Holbrook	99	95	2430	
Japanese	C. H. Robinson, Brandon..Landon	99	90	1080	
Japanese	L. S. Robie, Hardwick..Small	96.87	....	6300	
Japanese	H. W. Myers & Co., Bennington..Small	96.03	....	6196	
German	Mathews & Hall, Orleans..Stanford	99.01	96	810	
German	A. B. Taylor, Manchester..Stanford	98.2	95	1638	
Japanese	E. I. Benson, Woodstock..Stanford	98.44	98.2	2250	

TABLE X—MILLET—Cont.

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound	Number ergoted seed per pound
Japanese	H. P. Munson, Morrisville..	Stanford	99.9	98.25	90	
Japanese	J. W. Gillis, Danville..	Stanford	98.44	85	2800	
Japanese	A. B. Taylor, Manchester..	Stanford	98.5	94	1820	
Japanese	M. P. Perley & Co., Enosburg Falls..	Stanford	95.41	....	10710	
Hungarian	H. P. Munson, Morrisville..	Stanford	96.21	96.5	14000	
Hungarian	Mathews & Hall, Orleans..	Stanford	99.32	96.5	2250	
Hungarian	J. E. Eaton & Son, Lyndonville..	Whitney-Eckstein	98.16	97	3900	
Hungarian	C. E. Miller, Wells River..	Whitney-Eckstein	98.11	96	6794	
Hungarian	J. E. Hewitt, South Royalton..	Whitney-Eckstein	99.24	....	2000	

TABLE XI—REDTOP

.....	R. L. Clark, Barre..	Bailey	75	99	239712	22704
Ace, Fancy	A. H. Winslow, Bennington..	Barber & Bennett	90.00	87.6	85806	18164
.....	LaFountain & Woolson, Springfield..	Breck	85.5	90	108450	....
B.	E. H. Button, Brandon..	Conklin	79.4	78	187502	....
Ace	E. J. Davis, Chester..	A. Dickinson	91.6	90	29964	27241
Ace	J. H. Carr, Hardwick..	A. Dickinson	92.5	95.5	24516	9084
Ace	Field & Lawrence, Bellows Falls..	A. Dickinson	91.8	92	65830	....
.....	C. A. Leland, Springfield..	Holbrook	89.00	....	1816	....
X	H. P. Munson, Morrisville..	Holbrook	85.00	90	149366	12258
White Mountain	S. E. Clark, Wells River..	Holbrook	97.5	95	6810	9988
Globe	W. C. Landon & Co., Rutland..	Holbrook	97.5	96	9080	19068
Ace	W. C. Landon & Co., Rutland..	Holbrook	92	90	78996	....
.....	Howard Hardware Co., Bellows Falls..	Small	53.5	92	16798	....
.....	J. W. Gillis, Danville..	Stanford	93	92.5	85352	....
.....	Stearns Bros., Springfield..	Whitney-Eckstein	82	....	91254	....
Fancy	E. T. Seabury Est., Waterbury..	Whitney-Eckstein	95	....	17252	....

*The presence of ergoted seed was declared on the package as required by law.

†The presence of ergoted seed was not declared on the package.

TABLE XII—TIMOTHY

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound	Number ergoted seed per pound
Globe	H. O. Holt & Co., Richford..	Bailey	99.82	99.7	400	....
Pine Tree	A. H. Winslow, Bennington..	Barber & Bennett.	99.25	99	681	....
Pine Tree	A. H. Winslow, Bennington..	Barber & Bennett.	99.5	99.5	681	....
Globe	A. H. Winslow, Bennington..	Barber & Bennett.	99.5	99.75	227	....
Bison	A. H. Winslow, Bennington..	Barber & Bennett.	99	98.4	2270	....
.....	LaFountain & Woolson, Springfield..	Breck	99.74	99.7	....	....
Acme	A. D. Pease, Burlington..	Conklin	99.8	99.8	None	....
King	E. M. Bixby & Son, Poultney..	Conklin	99.55	99.6	None	....
Rex	Geo. Stannard, Fair Haven..	Conklin	99	98.4	1362	....
Bingo	F. W. Barrett, Poultney..	Conklin	99.95	99.95	None	....
Archer	H. A. Slayton & Son, Morrisville..	A. Dickinson	96	95.5	17479	681†
Colonial	A. H. McLeod Mill. Co., St. Johnsbury..	A. Dickinson	99.1	98.5	2724	....
Pine Tree	A. H. McLeod Mill. Co., St. Johnsbury..	A. Dickinson	99.6	99.5	1362	....
Globe	A. H. McLeod Mill. Co., St. Johnsbury..	A. Dickinson	99.8	99.7	681	....
Bison	A. H. McLeod Mill. Co., St. Johnsbury..	A. Dickinson	98.3	97.5	6583	....
Bison	A. H. McLeod Mill. Co., St. Johnsbury..	A. Dickinson	99	98	2724	....
Bison	J. H. Carr, Hardwick..	A. Dickinson	98.2	97.6	8853	....
.....	Howard Hardware Co., Bellows Falls..	Flagg's	98.4	....	3000	225†
Globe	Griswold & Mackinnon, St. Johnsbury..	Griswold & Mack..	99.79	99	748	....
Bison	Griswold & Mackinnon, St. Johnsbury..	Griswold & Mack..	97.58	97.5	11500	700†
Half Century ...	Half Century Store Co., Randolph..	Half Century	99.62	99.7	170	....
X	F. M. Kempton, Barre..	Holbrook	95.25	93	65700	....
Globe	E. Lane & Son, Newport..	Holbrook	99.5	99.7	1575	....
White Mountain..	Clark & Davison, Groton..	Holbrook	99.74	99.6	434	....
White Mountain..	H. P. Munson, Morrisville..	Holbrook	99.75	99.7	681	....
Bright Hulled Globe	W. C. Landon & Co., Rutland..	Holbrook	99.5	99.7	227	....

†The presence of ergoted seed was not declared on the package.

TABLE XII—TIMOTHY—Cont.

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound	Number ergoted seed per pound
Monadnock	Howard Hardware Co., Bellows Falls..	Holbrook	99.75	99.5	227	....
Pine Tree	Adams & Davis, Chester..	Holbrook	99.75	99.7	1135	....
XX	J. H. Carr, Hardwick..	Holbrook	98.87	98.5	681	....
Runad	J. W. Jones & Co., Burlington..	Illinois	99.38	....	None	....
Johnson's Choice..	H. G. Folsom, St. Albans..	Johnson	99.45	99.5	900	....
No. 6677	E. H. Heminway, Manchester..	Landon	99.45	99	404	....
Pine Tree	C. H. Robinson, Brandon..	Landon	99.95	99.5	227	....
Pine Tree	H. E. Shaw, Stowe..	Pine Tree	99.79	99.5	158	....
Oriole	H. F. Estabrook, St. Johnsbury..	Scarlett	99.52	99.5	180	....
Oak	H. F. Estabrook, St. Johnsbury..	Scarlett	99.06	98	2000	....
Minnesota.....	L. S. Robie, Hardwick..	Small	99.02	....	5850	....
Climax	W. C. Landon & Co., Rutland..	Small	99.42	99	90	....
.....	S. P. Curtis & Son, Rutland..	Small	98.95	99.12	2192	3821
.....	S. P. Curtis & Son, Rutland..	Small	98.55	98.5	4620	....
Eclipse	F. M. Sherman & Co., Newport..	Small	99.6	98	7115	....
Pine Tree	C. F. Stevens, Randolph..	Spauld'g & Kimball	99.27	99.5	None	....
Liberty	L. E. Avery & Son, Vergennes..	Stanford	99.5	99.5	681	....
.....	E. I. Benson, Woodstock..	Stanford	98.75	96.7	19000	....
Prime	Ray P. Webster, Barton..	Stanford	99.25	99	3740	5104
Strictly Prime ...	Mathews & Hall, Orleans..	Stanford	99	96.5	6300	....
Honor	A. B. Taylor, Manchester..	Stanford	99.6	99.7	227	....
Dandy	L. E. Avery & Son, Vergennes..	Stanford	98.9	99	1362	....
Gold Medal	Hardwick Hardware Co., Hardwick..	Whitney-Eckstein	99.94	99.7	None	....
Pan-American ...	Ray P. Webster, Barton..	Whitney-Eckstein	98.81	99.5	900	....
Green Mountain..	E. E. Harris, Morrisville..	Whitney-Eckstein	99.17	99.5	225	....
Frontier	E. E. Harris, Morrisville..	Whitney-Eckstein	97.25	96	5000	4504
Herald	Ray P. Webster, Barton..	Whitney-Eckstein	98.81	98	6660	....

†The presence of ergoted seed was not declared on the package.

TABLE XIII—MISCELLANY

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound
BARLEY					
Six Row	F. M. Sherman & Co., Newport..	Bailey	96.63	99.5	30
Six Row Oderbrucker ..	Clark & Davison, Groton..	Conklin	95.49	98	30
Six Row Oderbrucker ..	E. M. Bixby & Son, Poultney..	Conklin	98.2	98.8	181
Six Row	E. J. Davis, Chester..	A. Dickinson....	98.23	98	None
Six Row Monadnock ...	Adams & Davis, Chester..	Holbrook	98.5	96	None
Beardless	Adams & Davis, Chester..	Holbrook*	99.4	....	120
Six Row Fancy	M. P. Perley & Co., Enosburg Falls..	Morehouse	96.5	99.5	30
.....	Miles & McMahon, Stowe..	Stanford	99.05	90	None
Six Row	C. McFarland & Son, Barton..	Stanford	98.12	90	15
Six Row	E. Lane & Son, Newport..	Whitney-Eckstein	98.12	....	None
.....	C. E. Miller, Wells River..	Whitney-Eckstein	98.13	....	150
.....	E. E. Harris & Co., Morrisville..	Whitney-Eckstein	98.4	....	10
*Bought prior to July 1, 1913. Wholesaler not liable.					
BLUE GRASS					
Fancy Kentucky Blue Grass	S. P. Curtis & Son, Rutland..	Conklin	92.73	82	15209
Kentucky Blue Grass	W. C. Landon & Co., Rutland..	Holbrook	95.5	....	2270
Kentucky Blue Grass	H. A. Myers & Son, Bennington..	Stanford	92.28	....	6574
BUCKWHEAT					
Buckwheat	Howard Hardware Co., Bellows Falls..	Holbrook	99.7	95	None
Japanese Buckwheat	M. P. Perley & Co., Enosburg Falls..	Morehouse	99.88	99.5	None
CLOVER, SWEET					
Sweet Clover	E. G. Davis, Chester..	A. Dickinson....	97.33	95	1208
Yellow Sweet Clover	W. C. Landon & Co., Rutland..	Holbrook	99.2	....	None
Sweet Clover	W. H. Adams, Vergennes..	Stanford	99.45	98.5	996

TABLE XIII—MISCELLANY—Cont.

Trade name	Name and address of retailer	Wholesaler	Actual percentage of purity	Guaranteed percentage of purity	Approximate number of weed seeds per pound
CLOVER, WHITE					
White Clover	A. H. Winslow, Bennington..	Barber & Bennett	97.75	97.5	2270
White Clover	A. H. McLeod Mill. Co., St. Johnsbury..	A Dickinson*	93.25	....	13166
White Clover	W. C. Landon & Co., Rutland..	Holbrook	79.5	....	16798
White Clover	LaFountain & Woolson, Springfield..	Stanford	98.56	96	11000
*Bought before July 1, 1913. The wholesaler is therefore not liable.					
ORCHARD GRASS					
Orchard Grass ...	A. H. Winslow, Bennington..	Barber & Bennett	91.75	74.66	2297
Orchard Grass ...	Griswold & Mackinnon, St. Johnsbury..	Griswold & Mack.	90	....	6700
Orchard Grass ...	H. P. Munson, Morrisville..	Stanford	98.3	....	2835
PEA					
Northern Excel- sior Pea	J. E. Eaton & Son, Lyndonville..	Breck	100	98	None
Pea	J. E. Eaton & Son, Lyndonville..	Emerson	100	98	None
Canada Pea	Clark & Davison, Groton..	Stanford	98.11	90	None
RAPE					
Essex Rape	Clark & Davison, Groton..	Stanford	93.44	85	22
SEED OATS					
Seed Oats	Arch. Batchelder, Plainfield..	Bailey	99.66	....	None
Southern Wonder Seed Oats	E. T. Seabury Est., Waterbury..	Conklin	99.84	99.5	28
White Mt. Seed Oats	W. C. Landon & Co., Rutland..	Holbrook	99.85	99	None
Seed Oats	H. S. Buttles Est., Brandon..	McEwen	99.95	....	None
Fancy White Oats	M. P. Perley & Co., Enosburg Falls..	Morehouse	99.55	99.5	None
Seed Oats	Combination Cash Store, Manchester..	Whitney-Eckstein	99.05	....	135
RYE					
Seed Rye	Burditt Bros., Rutland..	A. Dickinson	99.06	95	None
WHEAT					
Spring Wheat....	M. P. Perley & Co., Enosburg Falls..	Morehouse	99.77	99.5	47*

*Corn cockle.

TABLE XIV—WHOLESALEERS.

E. W. BAILEY & CO., MAIN ST., MONTPELIER, VT.

Kind of seed	Brand	Purity found	Purity guaranteed	Approximate number of weed seeds per pound	Approximate number of ergoted seed present in a pound
Alsike Clover	Ace	94.68	93.7	7120	....
	Ace	94.8	93.7	7381	....
	Ace	98.8	99.5	3375	....
Red Clover	Ace	98.86	98.5	4050	....
	No name	98.81	98	2970	....
Corn	Improved Leaming	99.69	90	....	....
	Early Mastodon	100	None	....	....
	Sanford White Flint Field	98.12	None	....	....
	Sanford White	98.92	99.6	....	....
	Longfellow	99.7	99.5	....	....
	Eureka	99.25	99.5	....	....
Redtop	No name	75	99	239712	2270†
Timothy	Globe	99.82	99.7	400	....
Miscellany	Barley, six row	96.63	99.5	30	....
	Seed Oats	99.66	None	....	....

†Presence of ergoted seed not declared as required by law.

BARBER & BENNETT, ARCH AND CHURCH STS., ALBANY, N. Y.

Red Clover	AA Medium	98.96	99	1080	....
	A Medium	99.1	98.9	630	....
Redtop	Ace Fancy	90	87.6	85806	1816*
Timothy	Pine Tree	99.25	99	681	....
	Pine Tree	99.5	99.5	681	....
	Globe	99.5	99.75	227	....
	Bison	99	98.4	2270	....
Miscellany	White Clover	97.75	97.5	2270	....
	Orchard Grass	91.75	74.66	2497	....

*Presence of ergoted seed declared by wholesaler in accordance with the law.

JOS. BRECK & SONS CORPORATION, 51-52 NORTH MARKET ST.,
BOSTON, MASS.

Alsike Clover	Prime	92.5	None	7254	....
Red Clover	Ace	99.22	98	900	....
	Prime	98.4	99.35	2160	....
	No name	98.5	96	2250	....
Corn	Perry's Hybrid	99.47	None	....	....
	Early Mastodon	99.51	None	....	....
	Longfellow Flint	99.35	99	....	....
	Sanford Flint	98.53	99	....	....
Redtop	No name	85.5	90	108450	....
Millet	Japanese	98.11	96.8	4081	....
	Japanese	99.4	....	450	....
	Japanese	98.47	....	3850	....
Timothy	No name	99.74	99.7	None	....
Miscellany	Northern Excelsior Pea	100	98	None	....

CHAMPLAIN SEED CO., BURLINGTON, VT.

Corn	Northern Sanford	96.36	99.95	....	....
	No name	100	99.95	....	....
	Burlington Dent	96.46	99.95	....	....
	Pride of Nashua	99.6	99.95	....	....

E. W. CONKLIN & SON, 28-48 MONTGOMERY ST., BINGHAMTON, N. Y.

Kind of seed	Brand	Purity found	Purity guaranteed	Approximate number of weed seeds per pound	Approximate number of ergoted seed present in a pound
Alfalfa	IXL	99.29	97.25	91	....
Alsike Clover	C. M.	95.2	95.45	2497	....
	C. M.	94	95	7718	....
Red Clover	C	91.7	87.65	19206	....
	Atlas Medium	98.6	97.25	1365	....
	Paragon Medium	98.8	98.25	819	....
	Crown Medium	99.52	99.25	1183	....
	Crown Mammoth	99.5	99.25	728	....
	Etna Mammoth	92	93.7	9191	....
	Atlas Mammoth	98.5	97.2	1638	....
Corn	Imperial Leaming	98.5	99	....	....
	Imperial Leaming	99.66	99.22	....	....
	White Sanford	98.78	98.28	....	....
Redtop	B	79.4	78	187502	....
Timothy	Acme	99.8	99.8	None	....
	King	99.55	99.6	None	....
	Rex	99	98.4	1362	....
	Bingo	99.95	99.95	None	....
Millet	Japanese	98.8	96.4	1638	....
	German	99.75	99.4	91	....
	German Prime	95.8	98.6	1220	....
	Choice Hungarian	97.4	99	7462	....
	Hungarian	97.8	99.2	6916	....
Miscellany	Barley, six row	95.49	98	30	....
	Barley, six row	98.2	98.8	181	....
	Fancy Ky. Blue Grass	92.73	82	15209	....
	Northern wonder seed oats	99.84	99.5	28	....

ALBERT DICKINSON CO., CHICAGO, ILL.

Alfalfa	Pine Tree	99.7	99.5	None	....
	Ace	99.02	99.3	546	....
Alsike Clover	Pine Tree	98.65	98	1080	....
	Globe	99.25	97	910	....
	Ace	92.8	93.7	9761	....
	Ace	93.5	95	9988	....
	Queen	86.5	87	14528	....
	Kaiser	90.44	87.8	18400	....
	Kaiser	92.25	91	18614	....
	Kaiser	91.7	92	15890	....
Red Clover	Ace	98.18	96	3185	....
	Ace	98.3	98	1729	....
	Ace	99.3	99.7	364	....
	Pine Tree	99.26	98	3825	....
	Pine Tree	98.9	99	910	....
	Globe	99.24	99.6	1092	....

ALBERT DICKINSON CO.—Continued

Kind of seed	Brand	Purity found	Purity guaranteed	Approximate number of weed seeds per pound	Approximate number of ergoted seed present in a pound
Red Clover.....	Globe	99.25	99	90	....
	Kaiser	96.7	97	7189	....
	Queen	91.6	91.4	10192	....
	Queen	97	96	3822	....
	Mammoth	98.5	98.4	2550	....
Corn	Sanford Flint	99.24	99	....	....
Redtop	Ace	91.6	90	29964	2724†
	Ace	92.5	95.5	24516	908†
	Ace	91.8	92	65830	....
Millet	Hungarian	98	97	3640	....
	Hungarian	95.6	98	2366	....
	Hungarian	99.8	98.3	273	....
	Japanese	98.5	99	1000	....
	Japanese	99.6	98	273	....
	Japanese	98.5	95	2639	....
	Japanese	98.64	95.5	2541	....
Timothy	Archer	96	95.5	17479	681†
	Colonial	99.1	98.5	2724	....
	Pine Tree	99.6	99.5	1362	....
	Globe	99.8	99.7	681	....
	Bison	98.3	97.5	6583	....
	Bison	99	98	2724	....
	Bison	98.2	97.6	8853	....
	Bison	98.23	98	None	....
Miscellany	Barley, two row	98.23	98	None	....
	Sweet Clover	97.33	95	1208	....
	White Clover	93.25	None	13166	....
	Rye	99.06	95	None	....

†Presence of ergoted seed not declared as required by law.

CRAVER-DICKINSON SEED CO., 329-351 GANSON ST., BUFFALO, N. Y.

Alsike Clover ...	Pine Tree	96.75	None	3632	....
	Ace	94.75	96.3	18841	....

THOMAS W. EMERSON, BOSTON, MASS.

Corn	Eureka	99.61	None	....	....
	Longfellow Yellow Dent...	98.31	None	....	....
	Sanford	98.62	None	....	....
Millet	Japanese	97.18	None	11305	....
Miscellany	Pea	100	98	....	....

GRISWOLD & MACKINNON, ST. JOHNSBURY, VT.

Kind of seed	Brand	Purity found	Purity guaranteed	Approximate number of weed seeds per pound	Approximate number of ergoted seed present in a pound
Corn	Sanford	99.22	99	....	....
Timothy	Globe	99.79	99	748	....
	Bison	97.58	97.5	11500	700†
Miscellany	Orchard Grass	90	None	6700	....

†Presence of ergoted seed not declared as required by law.

HALF CENTURY STORE CO., RANDOLPH, VT.

Timothy	Half Century	99.62	99.7	170	
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HOLBROOK GROCERY CO., KEENE, N. H.

Alsike Clover	...XX	81.08	78	32625	
	X	69.54	70	39925	
	Globe	98.75	99	450	....
	XXX	93.74	90	8775	....
	White Mountain	99.5	98	454	....
Red Clover	...Ace	99.2	98	540	....
	Ace	98.2	96.8	330	....
	Queen	98.2	96	3600	....
	White Mountain	99.2	99.5	90	....
	Globe	99.3	99	500	....
	XXX	97.32	96.5	4929	....
	Monadnock	99.4	99	540	....
	XX	92.35	90	10962	....
	No name	94.2	90	2700	....
	No name	91.44	80	24800	....
	No name	91.65	80	33300	....
Corn	Leaming	98.89	99	....	....
	E. C. F.	98.39	99	....	....
Redtop	...No name	89	None	1816	....
	X	85	90	149366	12258†
	Globe	97.5	96	9080	19068†
	White Mountain	97.5	95	6810	9988†
	Ace	92	90	78996	....
Millet	German	99.4	97.5	None	....
	German	97.2	96	None	....
	Japanese	95.5	90	11250	....
	Monadnock Hungarian	98.6	97	2880	....
	Monadnock Hungarian	99.6	98	1890	....
	XX Hungarian	99.5	97	810	....
	X Hungarian	99	95	2430	....
Timothy	...X	95.25	93	65700	....
	Globe	99.5	99.7	1575	....
	White Mountain	99.74	99.6	434	....
	White Mountain	99.75	99.7	681	....

†Presence of ergoted seed not declared as required by law.

HOLBROOK GROCERY CO.—Continued

Kind of seed	Brand	Purity found	Purity guaranteed	Approximate number of weed seeds per pound	Approximate number of ergoted seed present in a pound
Timothy	Bright Hulled Globe	99.5	99.7	227	....
	Monadnock	99.75	99.5	227	....
	Pine Tree	99.75	99.7	1135	....
	XX	98.87	98.5	681	....
Miscellany	Barley, Monadnock (6 row)	98.5	96	None	....
	Barley, Beardless	99.4	None	120	....
	Kentucky Blue Grass	95.5	None	2270	....
	Buckwheat	99.7	95	None	....
	Sweet Clover Yellow Blox.	99.2	None	None	....
	White Clover	79.5	None	16798	....
	White Mt. Seed Oats	99.85	99	None	....

ILLINOIS SEED CO., 1521-1535 SOUTH PEORIA ST., CHICAGO, ILL.

Timothy	Runad	99.38	None		
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W. B. JOHNSON & CO., ESSEX JUNCTION, VT.

Timothy	Johnson's Choice	99.45	99.5	900	
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W. C. LANDON & CO., RUTLAND, VT.

Millet	Japanese	99	90	1080	
Timothy	No. 6677	99.45	99	404	
	Pine Tree	99.95	99.5	227	

R. H. McEWEN MILLING CO., OGDENSBURG, N. Y.

Miscellany	Seed Oats	99.95			
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MICHIGAN SEED CO., BURLINGTON, VT.

Corn	Golden Nugget	98.34	None		
	Vermont Dent	99.31	None		

J. O. MIDDLEBROOK & SONS, COLLEGE ST., BURLINGTON, VT.

Corn	King of Earliest	99.91	95	....	....
	Sanford Flint	100	95	....	....
	Improved Leaming	99.69	95	....	....
	Early Mastodon	98.77	95	....	....

W. H. MOREHOUSE & CO., 46-47 PRODUCE EXCHANGE, TOLEDO, OHIO

Kind of seed	Brand	Purity found	Purity guaranteed	Approximate number of weed seeds per pound	Approximate number of ergoted seed present in a pound
Alfalfa	Anchor Bulkcd Fancy	99.5	None	454	....
Alsike Clover	Blue Jay	99.25	98.5	675	....
	Bell	97.47	97	671	....
	Anchor	99.58	99.5	444	....
Red Clover	Anchor	99.48	None	180	....
	Bell Toledo	99.4	99.5	900	....
	Michigan Golden Dent	99.17	99.5	....	....
Corn	Eureka White	98.11	99.5	....	....
	Longfellow Yellow Flint	98.91	99.5	....	....
	Stowell's Evergreen	99.21	99	....	....
	Southern White	98.85	99.5	....	....
	Leaming	99.91	99.5	....	....
	Barley, Six Row Fancy	96.5	99.5	30	....
Miscellany	Japanese Buckwheat	99.88	99.5	....	....
	Oats, Fancy White	99.55	99.5	....	....
	Spring Wheat	99.77	99.5	47*	....

*Corn cockle.

PAGE SEED CO., GREENE, N. Y.

Corn	Pride of the North	98.71	None	....	....
	Page's Genesee Valley Flint	98.10	90	....	....
	Golden Nugget	97.46	None	....	....
	Eureka	100	None	....	....
	Leaming	98.36	None	....	....
	Leaming	98.36	90	....	....
	Page's High Bred Eureka	99.58	90	....	....
	Page's Early Triumph	99.05	90	....	....
	Stowell's Evergreen	99.57	90	....	....
	No name	100	None	....	....
	Longfellow	98.76	None	....	....

JEROME B. RICE SEED CO., CAMBRIDGE, N. Y.

Corn	Sanford	96.12	None	....	....
	Leaming	98.3	None	....	....
	Eureka	97.54	90	....	....
	Eureka	95.16	None	....	....
	Eight Rowcd Canada	99.98	None	....	....
	Triumph Field	98.75	90	....	....
	Early Mastodon	98.32	None	....	....
	100 Day Dent Golden	98.3	None	....	....
	Pride of the North	98.6	None	....	....
	Early Northern Flint	99.4	90	....	....

ROSS BROS. CO., WORCESTER, MASS.

Kind of seed	Brand	Purity found	Purity guaranteed	Approximate number of weed seeds per pound	Approximate number of ergoted seed present in a pound
Corn	Eureka	99.34	None	....	....

WM. G. SCARLETT & CO., 729-735 EAST PRATT ST., BALTIMORE, MD.

Alsike Clover ...	Oak	98.76	96	8379	....
Red Clover	Oak	98.81	97.2	3116	....
Timothy	Oriole	99.52	99.5	180	....
	Oak	99.06	98	2000	....

W. H. SMALL & CO., EVANSVILLE, IND.

Alfalfa	Eclipse	99	98	1820	....
Alsike Clover ...	Eclipse	94.75	97.5	7650	....
	No name	94.03	98.5	9460	....
Red Clover	Old Style Fancy	89.86	None	23205	....
	Climax Superfine	98.38	99.04	7200	....
	Eclipse	91.97	None	20995	....
Redtop	No name	53.5	92	16798	....
Millet	Japanese	96.87	None	6300	....
	Japanese	96.03	None	6196	....
Timothy	No name	98.95	99.12	2192	382†
	No name	98.55	98.5	4620	....
	No name	98.4	....	3000	225†
	Eclipse	99.6	98	7115	....
	Minnesota	99.02	None	5850	....
	Climax	99.42	99	900	....

†Presence of ergoted seed not declared as required by law.

SPAULDING & KIMBALL CO., BATTERY ST., BURLINGTON, VT.

Alsike Clover ...	Queen	86.75	87.5	9988	....
Red Clover	Queen	94.34	94.8	4263	....
Timothy	Pine Tree	99.27	99.5	None	....

STANFORD SEED CO., 93 PERRY ST., BUFFALO, N. Y.

Alfalfa	Empire	99.3	99.52	None	....
	Fancy	99.86	99.5	180	....
Alsike Clover ...	Arc	98.1	96.8	4000	....
	Arc	98.57	97.5	None	....
	Arc	99.2	98	225	....
	Arc	96.3	95.8	1260	....
	None	98.84	98.8	None	....
	W	96.57	96	1776	....
	Honor	99.4	97	None	....
	Honor	98.61	98.75	450	....
	Fancy	97.64	96.75	3960	....
	Fancy	97.88	96.8	2700	....
	Reliable	98.57	97.5	220	....

STANFORD SEED CO.—Continued

Kind of seed	Brand	Purity found	Purity guaranteed	Approximate number of weed seeds per pound	Approximate number of ergoted seed present in a pound
Red Clover	Honor Brand Medium	99.28	99.25	1800	.....
	Choice Medium	97.06	94	15000	.....
	Arc Medium	99.24	99.2	1800	.....
	Arc Medium	99	99	1400	.....
	Arc Mammoth	99.53	99	1400	.....
	Arc Mammoth	99.6	98.5	1000	.....
	Arc	99.43	99.25	450	.....
Corn	Imp. Early Canada Flint	98.14	90	.....	.....
	Improved Flint Longfellow	99.61	90	.....	.....
	Improved Early Triumph	97.36	90	.....	.....
	Golden Dent	98.97	90	.....	.....
	Imp. Stowell's Evergreen	99.71	90	.....	.....
	Imp. Stowell's Evergreen	99.66	95	.....	.....
	Eureka	99.97	95	.....	.....
	Eureka	97.8	None	.....	.....
	Eureka	99.67	90	.....	.....
	Golden Nugget	99.7	90	.....	.....
	Golden Nugget	98.12	90	.....	.....
	Longfellow Flint	98.8	95	.....	.....
	Sanford Flint	100	95	.....	.....
	Sanford Flint	97	90	.....	.....
	Sanford	99.04	90	.....	.....
	Sanford	100	95	.....	.....
	100 Day Dent	99.85	90	.....	.....
	Longfellow Flint	97.66	90	.....	.....
	Improved Leaming	97.5	90	.....	.....
	Improved Leaming	99.65	90	.....	.....
	Golden Harvest	98.07	90	.....	.....
Redtop	Improved Sanford Flint	99.55	90	.....	.....
	Pride of the North	99.15	95	.....	.....
Millet	Leaming	98.91	90	.....	.....
	Early Triumph	99.4	95	.....	.....
	None	93	92.5	85352	.....
	German	99.01	96	810	.....
	German	98.2	95	1638	.....
	Japanese	98.44	98.2	2250	.....
	Japanese	99.9	98.25	90	.....
Timothy	Japanese	98.44	85	2800	.....
	Japanese	98.5	94	1820	.....
	Japanese	95.41	None	10710	.....
	Hungarian	96.21	96.5	14000	.....
	Hungarian	99.32	96.5	2250	.....
	Liberty	99.5	99.5	681	.....
	No name	98.75	96.7	19000	.....
	Prime	99.25	99	3740	510†
	Strictly Prime	99	96.5	6300	.....
	Honor	99.6	99.7	227	.....
	Dandy	98.9	99	1362	.....

†Presence of ergoted seed not declared as required by law.

STANFORD SEED CO.—Continued

Kind of seed	Brand	Purity found	Purity guaranteed	Approximate number of weed seeds per pound	Approximate number of ergoted seed present in a pound
Miscellany	Barley	99.05	90	None	....
	Barley, Six Row	98.12	90	15	....
	Kentucky Blue Grass	92.28	None	6574	....
	Sweet Clover	99.45	98.5	996	....
	White Clover	98.56	96	11000	....
	Orchard Grass	98.3	None	2835	....
	Canada Pea	98.11	90	None	....
	Essex Rape	93.44	85	22	....

L. TEWELES SEED CO., 113-119 CLYBOURNE ST., MILWAUKEE, WIS.

Corn	Evergreen Sweet Fodder	99.35	100		
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JOHN B. VARICK CO., MANCHESTER, N. H.

Alfalfa	Ace	99.3	99	182	
Red Clover	Ace	99.66	98	625	

WHITNEY-ECKSTEIN SEED CO., 599-601 PERRY ST., BUFFALO, N. Y.

Alfalfa	No name	99.62	99.7	180	....
Alsike Clover	Frontier	92.82	85	3016	....
	Pan American	99.31	97	450	....
	Pan American	96.74	97	2968	....
	Eureka	99.5	98.5	454	....
	Fancy	97.95	97	5580	....
	Export Fancy	98.74	98	764	....
Red Clover	Pan American	98.66	None	2282	....
	Pan American	96.68	None	4472	....
	Medium	97.43	98	6035	....
	Mammoth	98.06	98	4200	....
	Herald	98.46	97	4576	....
	Frontier	94.12	92	7380	....
	Eureka	99.56	99	900	....
Redtop	No name	82	None	91254	....
	Fancy	95	None	17252	....
Millet	Hungarian	98.16	97	3900	....
	Hungarian	98.11	96	6794	....
	Hungarian	99.24	None	2000	....
Timothy	Herald	98.81	98	6660	....
	Gold Medal	99.94	99.7	None	....
	Pan American	98.81	99.5	900	....
	Green Mountain	99.17	99.5	225	....
	Frontier	97.25	96	5000	450†
Miscellany	Barley, Six Row	98.12	None	None	....
	No name	98.13	None	150	....
	No name	98.4	None	10	....
	Seed Oats	99.05	None	135	....

†Presence of ergoted seed not declared as required by law.

F. H. WOODRUFF, MILFORD, CONN.

Corn	Sanford White	97.05	None		
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NOTE:—The abbreviations of the wholesalers' names appearing in tables VI-XIII, pages 17 to 39, are explained as follows:

Bailey—E. W. Bailey & Co., Montpelier, Vt.
Barber & Bennett—Barber & Bennett, Albany, N. Y.
Breck—Jos. Breck & Sons Corporation, Boston, Mass.
Champlain—Champlain Seed Co., Burlington, Vt.
Conklin—E. W. Conklin & Son, Binghamton, N. Y.
A. Dickinson—Albert Dickinson Co., Chicago, Ill.
Craver-Dickinson—Craver-Dickinson Seed Co., Buffalo, N. Y.
Emerson—Thos. W. Emerson, Boston, Mass.
Griswold & Mack—Griswold & Mackinnon, St. Johnsbury, Vt.
Half Century—Half Century Store Co., Randolph, Vt.
Illinois—Illinois Seed Co., Chicago, Ill.
Johnson—W. B. Johnson & Co., Essex Junction, Vt.
Landon—W. C. Landon & Co., Rutland, Vt.
McEwen—R. H. McEwen Milling Co., Ogdensburg, N. Y.
Michigan—Michigan Seed Co., Burlington, Vt.
Middlebrook—J. O. Middlebrook & Sons, Burlington, Vt.
Morehouse—W. H. Morehouse & Co., Toledo, O.
Page—Page Seed Co., Greene, N. Y.
Rice—J. B. Rice Seed Co., Cambridge, N. Y.
Ross—Ross Bros. Co., Worcester, Mass.
Scarlett—Wm. G. Scarlett & Co., Baltimore, Md.
Small—W. H. Small & Co., Evansville, Ind.
Spau'g & Kimball—Spaulding & Kimball Co., Burlington, Vt.
Stanford—Stanford Seed Co., Buffalo, N. Y.
Teweles—L. Teweles Seed Co., Milwaukee, Wis.
Varick—John B. Varick Co., Manchester, N. H.
Whitney-Eckstein—Whitney-Eckstein Seed Co., Buffalo, N. Y.
Woodruff—F. H. Woodruff, Milford, Conn.

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University of Vermont and State Agricultural College

Vermont Agricultural Experiment Station

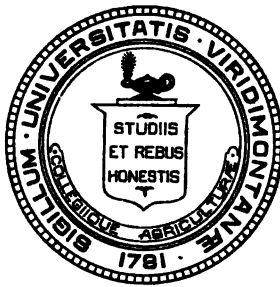
BURLINGTON, VERMONT

STUDIES IN TOLERANCE OF NEW ENGLAND
FOREST TREES

III. DISCONTINUOUS LIGHT IN FORESTS

by G. P. BURNS

(Vermont forestry publication 20)



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BULLETIN 193: STUDIES IN TOLERANCE OF NEW ENGLAND FOREST TREES

III. DISCONTINUOUS LIGHT IN FORESTS

BY GEORGE P. BURNS

INTRODUCTION

At present the only measure of the so-called "tolerance of forest trees" is the appearance of trees as they grow under the influence of the physical and biotic factors of a given habitat. If the trees are developing slowly, they are "intolerant"; if they are developing rapidly, they are "tolerant."

The factors then that determine "tolerance" are the factors of the habitat; and any study of forest succession, whether natural or artificial, requires an analysis of all those factors, of which light is only one. Upon entering the forest, the lowered intensity of the light is strikingly manifest. No other physical factor is so markedly altered. Hence one naturally associates the variation in the forest vegetation with the light conditions. A poorly developed lot of seedlings is supposed to result from the weakened or filtered light under the dominant trees; and the suppressed trees are supposed to be suppressed because of the changed light conditions.

Zon and Graves (16) in a discussion of the relation of light to tree growth have stated admirably the problems of tolerance. They cite literature indicating that many factors other than light influence tolerance. These authors conclude that we are "far from a thorough understanding of the effect of light upon the individual tree and especially on the trees in the forest." Almost every page suggests problems in plant physiology which must be solved and their work is well adapted to "stimulate an interest in further research in determining more accurately the light requirements of our forest trees, especially by measurements of light in the forests."

Fricke (5) dug ditches around certain plots thus relieving the "suppressed" trees growing thereon from the competition which existed between their root-systems and those of the dominant trees. Not only did vigorous young seedling trees grow in these isolated plots, but there also appeared a "luxuriant herbaceous vegetation strikingly different from that in the surrounding forest." The forest cover was not altered and without any change in the light conditions, the suppressed vegetation began a vigorous growth, seeming to indicate that

"root competition" was at fault rather than light shortage in cases of suppression. Hartig (8) says that, on a good soil, a given number of leaves will produce more substance than will the same number of leaves on a poor soil. "The growth of a tree may suddenly double or treble without increase in leaf surface or light intensity if the nourishment of the roots is greatly increased." He thus clearly recognizes soil conditions as a limiting factor in the growth of trees.

Tolerance, then, in the strict and proper sense of the term, represents the ability of a tree to thrive under the conditions of soil moisture, light, humidity, etc., found in any given habitat. However, this word is so established in our literature as expressing a light relationship only, that it will be difficult to superimpose the meaning just indicated. A clear understanding of the problem of forest succession and forest reproduction would be more easily attained in all probability if the word were elided from forestry literature.

LIGHT MEASUREMENTS IN FORESTS

The present bulletin attempts to determine the value of "light measurements in the forest" and to determine their significance in a study of the light requirements of our forest trees.

Light reaches the forest floor in four ways, through the tree crowns, between the tree crowns, reflected from leaves and twigs, and through the leaves themselves. The light which passes through the leaves is altered in composition; the rest is white light. Obviously, then, the kind and intensity of light vary greatly in forests of different species of trees.

The study of light intensities in the forests has been made along two distinct lines, according as the workers have emphasized the importance either of weakened white light or of filtered light in forest growth and reproduction and in the development of the vegetation of the forest floor.

FILTERED LIGHT IN FORESTS

Zederbauer (15) made a study of the light which passed through the leaves of several different species of plants and found that there was some variation in the rays absorbed. He argued therefore that the light in the forest must be altered in composition as it passes through the crowns. Accordingly he undertook to study the light in forests with a spectroscope. The stations selected were located in pure stands with the first branches ten meters from the ground and were situated



PLATE I. Cassandra, dead, under tamarack trees.



PLATE II. *Taxus canadensis*. At times a few rays of sunshine reach into the deepest recesses.



PLATE III. Reproduction of maple along the roadway running north and south. The seedlings receive full light during part of the day and are relieved also from competition with the roots of the adjacent forest trees.

far enough from the forest margin to be beyond the influence of side light. He found that all trees absorb between Fraunhofer lines B and C in the red end of the spectrum, then in the region about F in the blue, and beyond H in the violet. Some tree species absorb practically all rays from F to H, while others allow many rays in the indigo region to pass through unabsorbed. Intolerant pine and larch absorb about the same in the red, blue, and violet sections, using practically all the red, but only small amounts of blue and violet. On the other hand the tolerant spruce and beech, besides red, absorb some orange and a large amount of blue, indigo, and violet rays. Ash and oak fall between these two extremes and allow many indigo rays to pass through unabsorbed.

Zederbauer's results, in part at least, are admitted to be inaccurate, because of defects in the apparatus. It will appear later that many other errors must be eliminated before reliable results can be obtained. The fact that leaves of various species of trees absorb different rays of light is interesting, but of itself proves nothing.

Knuchel (10) undertook an exhaustive study of this subject and published a great mass of data which was reviewed by Sponsler (13). His methods were much more refined than those of Zederbauer, and his results are accordingly more trustworthy. His study was devoted especially to the variations in the composition of light which had passed through leaves, through forest crowns and through individual crowns. In the first case he used both sun and shade leaves of basswood, beech, ash, maple, etc. On account of their size no attempt was made to use softwood leaves. Only one illustration of his work with leaves need be given. On July 8, 1911, he took measurements of the composition of diffuse light after it had passed through leaves of the beech and obtained the following results:

TABLE I—COMPOSITION OF LIGHT AFTER PASSING THROUGH BEECH LEAVES
(KNUCHEL)

Rays passing	Sun leaves		Shade leaves	
	One leaf percent average	Two leaves percent	One leaf percent average	Two leaves percent
Red	2.5	0	11	2
Yellow	13	0	18.5	3
Green	6	0	16.5	1
Light blue	2	0	5	0
Dark blue	0	0	1	0

Since the sun leaves receive the light first and use the greater part of it, it would seem reasonable to assume that the filtered light is not of much use to the leaves within the crown.

Both hardwoods and softwoods were employed in Knuchel's study of the composition of light in the forests and under single trees. Some of the former consisted of beech, ash, birch and basswood, the latter of spruce, Scotch pine and silver-fir. He set up his spectroscope and made readings in the open. He then moved it into the forest to a previously selected typical or average station and made readings for that forest. Comparisons should enable one to determine the proportion of the total rays absorbed by the crowns. The subjoined table is typical, both for forest and single trees.

TABLE II—COMPOSITION OF LIGHT UNDER CROWNS OF BEECH AND SPRUCE
(KNUCHEL)

Beech	Single tree (heavy crown) Single reading percent	Forest Young stand Average reading percent	Old stand Average reading percent
Red	1	3.5	4.5
Yellow	4	6.6	6.4
Green	3	5.4	4.9
Light blue	1	2.6	3.6
Dark blue	1	2.4	3.1

Spruce	Grade A Average reading	Grade B-C Light clearing Average reading	Heavy clearing Average reading
Red	4.2	13.8	33.2
Yellow	5.2	14	33.7
Green	5.5	13.2	34.8
Light blue	4.1	12.5	32.8
Dark blue	4	12.4	32

Knuchel finds that the light under the crowns in hardwood forests has a similar composition to that passing through the leaves of the species composing the forest. The exception found was in the presence of blues in the former case. These blues, he says, come through the openings within the crowns. Under softwoods he found no color especially prominent, the light possessing the same composition as the light in the open; that is to say, no selective absorption was observed.

The present writer doubts whether valuable data can be obtained by the use of the spectroscope in the forest. It seems to him quite clear that the selection of a forest station for spectroscopic work which will represent the average of the forest cover and at the same time be as small as the opening which admits light to the spectroscope, is a difficult if not an impossible task. Furthermore the trustworthiness of the comparisons of these light values with the observations made in the open is questionable, since many changes both qualitative and quantitative in character may occur in light values while the instru-

ment is being moved to a new location and adjusted. Knuchel points out somewhat in detail this possibility of error.

In the solution of the problem of forest succession, little is gained by showing that the weakened light which passes through the sun leaf is comparatively rich in yellow and green rays, unless it is shown experimentally that this light is able to decompose carbon dioxide and otherwise influence the development of the seedlings of the future forest. Our knowledge of the value of the different rays of light in the development of plants is so rudimentary that great care should be used in drawing general conclusions in view of the lack of experimental data.

Further and valuable observations have been made by other workers in this field who have attempted to discover the amount of light actually passing through the leaves unabsorbed, and, finally, to determine the ability of such light to decompose carbon dioxide. For example Linsbauer (11) has determined the amounts of light which pass through sun and shade leaves of the same species and through sun leaves of different species. His results indicate that more light passes through the shade leaves than the sun leaves of the same species, but that the intensities are greatly reduced as shown by the following table, which represents only a small part of his data.

TABLE III—AMOUNT OF LIGHT PASSING UNABSORBED THROUGH LEAVES
(LINSBAUER)

	Sun leaf	Shade leaf
<i>Acer platanoides</i>	.0008	.005
<i>Carpinus Betulus</i>	.003	.008 average
<i>Cornus sanguinea</i>	.0004 average	.003
<i>Fagus sylvatica</i>	.0046 average	.02
<i>Fraxinus excelsior</i>	.001	.005
<i>Quercus Robur</i>	.006	.003
<i>Rhamnus cathartica</i>	.003	.008
<i>Ulmus montana</i>	.003	.0075 average

He found that the amount of light passing unabsorbed through sun leaves varies with different species from .006 to .0003, totality equaling 1, and that in the case of shade leaves the figures varied from .003 to .02. For a given tree with both sun and shade leaves, the amount of light passing through the leaf unabsorbed decreased from the center of the crown toward the periphery. If the leaves of the tree were formed to use the greatest possible amount of total light available, exactly the opposite result would be expected. Only in the case of *Quercus Robur* did the sun leaves allow more light to pass through unabsorbed than did the shade leaves.

Griffon (7) studied the action of the light which had passed through leaves. He placed a privet leaf in a chamber with a known percent of carbon dioxid, usually about 9 percent, and placed over the top one or more leaves of the plants undergoing observation. In this way all the light reaching the privet leaf was forced to pass through the experimental leaf. A gas analysis made at the close of the trial enabled him to determine the amount of carbon dioxid which the privet leaf had used. He thus determined the fact that light which passed through one leaf of many species was still strong enough to decompose carbon dioxid, when present in amounts of 5 to 10 percent, but that the rapidity of the process was greatly reduced by this preliminary filtration. In the sycamore maple this was reduced 48 times, but in the beech only seven times. When two leaves were interposed, no decomposition of carbon dioxid whatsoever took place, save that a very feeble action was observed under the two beech leaves. Such data show that although some light passes unabsorbed through both sun and shade leaves and that in some cases it is able to decompose carbon dioxid, yet the amount which passes is so small that it cannot play an important part in the nutrition of the trees or in forest succession. It would seem probable then that a weakened white light rather than a filtered light is the controlling factor in the development of all trees (14).

WEAKENED WHITE LIGHT IN FORESTS

The intensity of the light falling on the forest floor as compared with the total light in the open has been studied by a number of workers. It is sufficient for present purposes to cite only a few of the results thus far obtained.

First among the students of the matter is Wiesner (14) who adapted the work of Bunsen and Roscoe to botanical research. Using photographic paper¹ he attempted to determine the light values in forests in many parts of the world and also the minimum light requirements for many plants. The following table has been compiled by Zon and Graves (16) from the works of Wiesner "for some of our native trees and shrubs and European species commonly grown here."

¹Critics of this method often fail to appreciate the fact that photosynthesis is not the only function of the plant affected by light.

TABLE IV—MINIMUM LIGHT REQUIREMENTS FOR SOME NATIVE TREES AND SHRUBS (WIESNER)

Species	Region	Approximate elevation feet	Minimum light intensity
<i>Pinus contorta</i>	Yellowstone Park, Wyo.	6,400	.1666
<i>P. contorta</i>	Yellowstone Park, Wyo.	8,500	.1562-.1449
<i>P. flexilis</i>	Yellowstone Park, Wyo.	6,000	.1250-.1111
<i>Picea parryana</i>	Yellowstone Park, Wyo.	8,000	.0166-.0161
<i>P. parryana</i>	Salt Lake City, Utah	4,000	.0156-.0143
<i>Pseudotsuga taxifolia</i>	Yellowstone Park, Wyo.	5,500-6,000	.0500
<i>Juniperus virginiana</i>	Yellowstone Park, Wyo.	6,000	.2000-.1428
<i>J. communis nana</i>	Yellowstone Park, Wyo.	6,000-8,000	.1111-.1041
<i>Acer glabrum</i>	Yellowstone Park, Wyo.	6,000	.0333
<i>A. saccharum</i> L.	Niagara Falls, N. Y. (600 ft.) and Pocatello Idaho	4,000	.0400-.0250
<i>Populus alba</i>	Utah and Idaho	3,000-4,000	.1250-.1000
<i>P. tremuloides</i>	Yellowstone Park, Wyo.	6,000	.2381-.1666
<i>P. acuminata</i>	Livingston, Mont.	4,500	.1250-.1098
<i>P. deltoides</i>	Colorado Springs, Colo.	6,000	.2500
<i>P. deltoides</i>	Billings, Mont.	3,100	.1111
<i>P. nigra italica</i>	Salt Lake City, Utah	4,250	.0476
<i>P. balsamifera</i>	Colorado Springs, Colo.	6,000	.0625
<i>Betula fontinalis</i>	Mam. Hot Springs, Wyo.	6,000	.0714
<i>Shepherdia argentea</i>	Yellowstone region near Livingston, Mont. ...	4,500	.0714
<i>Vaccinium myrtillus</i>	Yellowstone region ...		.0602

Additional data taken from Wiesner's work appears below.

TABLE V—AVERAGE MINIMUM LIGHT INTENSITY REQUIRED (WIESNER)

Species	Light intensity Average			
<i>Fagus sylvatica</i>		0.016		
<i>Acer platanoides</i>		0.018		
<i>A. campestre</i>		0.023		
<i>A. negundo</i>		0.034		
<i>Thuja occidentalis</i>		0.050		
<i>Pinus Laricio</i>		0.099		
<i>Betula verrucosa</i>		0.111		
<i>Populus monilifera</i>		0.166		
<i>Fraxinus excelsior</i>		0.171		
<i>Larix decidua</i>		0.200	0.166	0.250
<i>Picea excelsa</i>	0.050	0.125	0.025	0.011

These figures represent the averages of many readings. In several cases such large variations in light intensities were found that more than one so-called minimum is given; for example, *Acer saccharinum*, not given in the table, has values of 0.200 and 0.143. Similar variations are given for *Larix decidua*. This tree has a so-called minimum of 0.166, 0.250 and 0.200. For *Picea excelsa* the following values are given: 0.011, 0.016, 0.025, 0.05, and 0.125. In the last case cited the great range in light required from 0.011 to 0.125 would seem to indicate that possibly the method used was not entirely trustworthy.

Clements (3), studying the conditions in mature forests of lodge-pole pine, found that the intensity of light in these forests varied from 0.12 to 0.05. He says "the values most frequently found were 0.08 and 0.07 which may well be taken as the normal." His lowest value was 0.016. Germination and growth were fairly good from 0.2 to 0.14, decreasing rapidly below the last named figures. When the light intensities were .08 to .05 there were no vigorous seedlings.

Pearson (12) found western yellow pine seedlings growing in habitats with average light intensities of 0.630 to 0.309. Only in intensities of 0.414 or better were the seedlings marked "good." Especially interesting in the data given for *Abies concolor*, where there seems to be little connection between the values given and the condition of the growing trees. In an intensity of 0.02 the trees were suppressed, while in light only a little stronger, 0.027 and 0.028, they were marked "good." The trees were doing well in light intensities of 0.048 and 0.068. This lack of uniformity in light requirement for the seedlings in each of these species must be due to some factor other than light, or else the method used is not trustworthy.

The following light values were taken from Pearson's readings, as given by Zon and Graves (16).

TABLE VI—LIGHT VALUES FOR WESTERN TREES (PEARSON)

Condition of seedlings	<i>Pinus ponderosa</i> Average light intensity	<i>Abies concolor</i> Average light intensity	<i>Pseudo tsuga taxifolia</i> Average light intensity
Good	.630	.068	.192
Good	.570	.048	.133
Good	.414	.028	...
Good	...	.027	...
Fair	.385	...	.097
Fair	.309	...	...
Poor	...	...	.049
Poor	...	...	.016
Suppressed	...	.020	...

Hesselman (9) noted great variations in light intensity under the shade of the plant groups which he studied. In some cases these variations amounted to as much as 300 percent. In groups of old spruces the light intensity was reduced to 0.044 and 0.037; in young spruce these values were 0.020 and 0.016.

Ciesler (2) measured light intensities in several types of forests, in each of which he took measurements after three grades of thinning. He found that forests which had been only lightly thinned held back a surprisingly large proportion of the light. The crowns of a severely thinned stand of fir absorbed about 80 percent, a beech stand 80 to 90

percent, and Austrian pine about 60 percent of the total light. In a beech stand which had been lightly thinned the crown absorbed 93 percent and a stand of Austrian pine similarly treated absorbed 80 percent.

The measurements here recorded vary so widely in respect to the so-called minimum that it would seem as if the accuracy of the method must be open to question.

LIGHT READINGS

The light values given in this section of the bulletin were made by the writer or his pupils, with the Clements type of photometer. This is a modification of the Bunsen-Roscoe-Wiesner instruments with which it is possible to make 25 separate readings in the field for each instrument. On account of its size and ease of operation it is adapted admirably to studies in the field. The usual method of operation is described by Clements (4) and need not be repeated here. In our work three persons were used in making the standard, one with a stopwatch, the other two with photometers. Exposures of from one to 25 seconds were made. Whenever possible this standard was made at actual noon on June 21; if clouds intervened at midday, on the first succeeding clear day. In the work done at Camp Bogardus, Douglas Lake, Mich., the standard was made the first clear day after work began. One of the strips of solio paper thus exposed was taken as the standard, glued to cardboard on which was indicated the length of exposure for each of the 25 tints thus obtained, wrapped in black paper and stored in a pasteboard box in the dark room where it was well protected from light and heat and showed little or no change during the season.

In actual work the readings taken in the field are compared with the standard in order to determine the light intensities. The matching of colors was done usually by one and the same person in order as much as possible to eliminate its personal equation. However, repeated tests made with several individuals have shown that appreciable difference in the light intensities as thus determined are uncommon. Hence it is safe to assume the essential accuracy of the observation. The light values determined when the standard was made were given the value "1," and all data were figured to this basis.

It is extremely difficult to get reliable data on the light intensity in the forest because the forest cover is not uniform, the light varies greatly within short periods of time, more particularly because of pass-

ing clouds, and there is no satisfactory instrument which will record accurately the light values during an entire day. As has been pointed out, there are many openings in the crowns of the individual trees and between the crowns of the adjacent trees, which cause an uneven shade on the ground. Indeed marked variations occur within a few feet. On this account great care must be taken in making exposures. In the studies now under review while making exposures in woods which were free from shrubs, the operator walked back and forth over a distance of 50 feet. The photometer was so held that the shadow of the body did not fall on the instrument at any time. In other habitats it was impossible to move the photometer through so great a distance, but in no case was it held stationary while an exposure was being made. Nevertheless despite precaution it is impossible to select an average station, for the personal equation is bound to be an all-important factor in its choice.

Absolutely cloudless days are few and far between in Michigan and Vermont. To be convinced of this fact one has only to attempt to make a study of light intensities. He will be struck with the fact that slight clouds pass almost continuously. Light variations which one would not notice ordinarily nevertheless are quite marked, even within the space of a few minutes. On this account, especially in the work of the past three years, simultaneous readings have been made. One person was left in the open control station while others went to the forest stations. If watches are compared and definite times for exposures are agreed upon, simultaneous readings can be made, even at stations which are widely separated. The lack of simultaneous readings is a serious source of error occurring in and vitiating much of the published data on light studies which are now extant. Knuchel (10) recognized this limitation of accuracy in his own work but was unable to rectify it because he did not have access to a sufficient number of instruments to enable him to make simultaneous readings. In the earlier work, before the need of simultaneous readings was felt so keenly, the author made observations at close intervals, usually five minutes apart, in order to avoid as much as possible the error due to changing light intensities in the open.

Even the velocity of the wind has been found to introduce errors in the readings taken in the forest, especially in hardwood forests. The movement of the leaves is an important factor in determining the amount of light passing to the interior of the crown or to the ground cover.

Undoubtedly one of the most serious errors in much of the published data on light intensities is due to the fact that many workers have taken their readings in the middle of the day and on bright clear days. Such readings, of course, are of little value in determining the amount of light available in a given habitat. However, intensities, measured at that time of day may be lower than those to be found in the same habitat earlier or later in the day. Some observations have shown that the maximum may be found before 9 A. M. or after 3 P. M. This is due to the fact that the sun, at different angles, throws varying amounts of light on a given habitat in the forest.

The data reported in this bulletin were gathered:

- (1) At First Sister Lake, a small post-glacial pond near Ann Arbor in Washtenaw County, Michigan, latitude about $42^{\circ} 20'$.
- (2) In the forests surrounding Douglas Lake, Cheboygan County, Michigan, latitude about $45^{\circ} 30'$.
- (3) Near Burlington, Vermont, latitude about $44^{\circ} 30'$.

1. FIRST SISTER LAKE

The vegetation of the bogs of the post-glacial lakes of southern Michigan has been described by several writers. A description of the conditions at this lake has been published somewhat in detail by the writer (1), who pointed out that the vegetation was arranged in zones, three of which were characterized by the dominance of certain trees, namely the *Larix*, *Populus-Acer*, and *Salix*. In some of these zones were found areas in which trees of other zones are prominent, for example *Larix*-*Populus* areas; in other places a pure stand of *Populus* was found which occupied a small area. Except in some parts of the *Larix* zone, more especially on the side toward the lake, the vegetation is not very dense. Most of the trees are small and the vegetation under them is quite abundant.

For a study of the light conditions in the tree zones, under the shade of the trees, the following stations were established; Control, *Larix*, *Larix*-*Populus*, *Populus*, *Populus-Acer*, and *Salix*. Readings were taken five minutes apart in most instances, beginning each day with the control station which was located near the water's edge. On some days and at some stations, five minutes or less was sufficient in which to make a reading, but in other cases 10 minutes or even more were necessary. Since there are six stations, it required a minimum of somewhat less than 30 minutes in which to take the readings and in many cases more than 60 minutes passed between the reading in the control and that of the *Salix* station.

The readings were taken at about the same time of day and the areas through which the photometer was moved were as nearly the same each time as could be estimated.

The result of this work is displayed in table VII. The values there given are directly comparable, as they all refer to the common standard, 1. In this instance the standard was made on April 27, a rather early date; but it seemed at that time desirable to make comparisons while the solio-paper used in making the readings was still fresh.

TABLE VII—LIGHT INTENSITIES AT CERTAIN STATIONS IN A PEAT BOG, COMPARED TO A COMMON STANDARD. MOST OF THE TREES WERE SMALL, AVERAGING ABOUT 30 FEET. FIRST SISTER LAKE, ANN ARBOR, MICH.

	5	April 11	19	27	8	10	May 17	24	31
Open	.0666	.2000	.6666	.8000	.5333	.5666	.1700	.2166	.5000
Larix	.0250	.0466	.0400	.2500	.1166	.1333	.0440	.0255	.0917
Larix-Populus ..	.0555	.1250	.7500	.6500	.4666	.4666	.2170	.1700	.3660
Populus	.0555	.1250	.4666	.3000	.2666	.3666	.1361	.1060	.1000
Populus-Acer ...	.0666	.1580	.6433	.6666	.3666	.5166	.1700	.2111	.2000
Salix	.0611	.1333	.3333	.6000	.3333	.4000	.2110	.1700	.2000

A careful consideration of these figures shows a wide divergence in the light intensities existing in the different zones when these are compared with one another. The only zone with consistently low intensities was the Larix, in which case variations ranged from .125 to .1333. In an adjacent Larix station, in which the cover vegetation was Cassandra in a dying condition, a series of readings gave a maximum light intensity of only .0333. (Plate 1). April 5 was a cloudy day with a light intensity of .0666 at the control station. A comparison of the values at other stations shows that with the exception of the Larix station there was very little variation. The same fact is apparent, but not so striking, in the data secured on May 17. On brighter days greater variations occurred, as may be seen by examining the data for April 27 and May 31. Possibly these wide variations are due to the fact that it is impossible to expose the photometer in exactly the same place when it is moved under the tree crowns. All possible care was taken to avoid error of this kind, but, as has been pointed out already, exactness in this respect cannot be obtained.

In some instances the light intensity "in the shade" was higher than in the open. (April 19, Larix-Populus station; May 17, same station and Salix station). Such occurrences tend to raise a doubt as to the actual value, indeed of the accuracy, of other readings. They are due, of course, to variations in the density of the clouds at the

times when different readings were made. These data emphasize the importance of simultaneous readings in any region where clouds occur.

It seemed desirable to determine the percent of light which was cut off by the various trees. The light value in the open each day being regarded as 1 and the readings taken at other stations figured to this basis, the data are presented in table VIII. The effect of the cover here is seen easily. If it is assumed, as is done usually, though without warrant, that the light intensity in the open did not vary while the six readings were being taken, the figures represent the amount of light that was held back by the trees.

For example, if on April 27 the light in the open is 1, then the crowns of *Larix* cut off 69 percent of the light, *Larix*-*Populus* 19 percent, *Populus* 63 percent, *Populus*-*Acer* 17 percent, and *Salix* 25 percent. A month later, however, on May 31, 82 percent, 27 percent, 82 percent, 60 percent and 60 percent were thus shut out. These consistent increments in shade may be due in part to the fact that the trees were more fully in leaf at the end of May than they were in late April. However, this fact cannot account for the variations found in comparing values obtained May 24 with those of May 31.

TABLE VIII—SHOWING THE AMOUNTS OF LIGHT HELD BACK BY THE TREES

	April 5	11	19	27	3	10	May 17	24	31
	%	%	%	%	%	%	%	%	%
Open	0	0	0	0	0	0	0	0	0
<i>Larix</i>	63	77	40	69	79	77	75	89	82
<i>Larix</i> - <i>Populus</i> ..	16	38	*	19	13	17	*	25	27
<i>Populus</i>	16	38	31	63	50	36	20	52	82
<i>Populus</i> - <i>Acer</i> ..	0	21	4	17	32	9	0	3	60
<i>Salix</i>	9	34	50	25	38	30	*	25	60

*Light stronger than it was in the open.

2. DOUGLAS LAKE

During the summer of 1909 the writer spent some time with advanced students studying the forest conditions in the neighborhood of Douglas Lake, Cheboygan County, Michigan, with a laboratory at Camp Bogardus. The camp was located at the edge of the lake and was in easy reach of several types of forests.

A general survey of the region indicated the existence in a general way of four types; *Acer*-*Fagus*-*Tsuga*, *Thuya*-*Fraxinus*-*Ulmus*, *Larix*, *Populus*—*Betula papyrifera*. Near the camp was a very deep ravine which widened rapidly toward the east. A series of springs yielding a daily flow estimated at 3,000,000 gallons, empties at the head

of the ravine. This water flows in a more or less well defined channel into Burt lake. Seven stations in close proximity were located near the head of this ravine. These were designated as *Acer*, *Fagus*, *Tsuga*, *Taxus*, *Mnium*, *Pinus strobus*, and *Acer rubrum*. As one leaves the hot sandy plain above and descends the steep winding path to the shady ravine, a drop of about 68 feet, physical conditions change rapidly. The relative humidity as determined by an average of eight readings, increase from 53 percent in the control in the sand plain to 83 percent in the ravine bottom; the air temperature at the surface of the soil decreases from 35° C. to 18° C., while on hot days the difference amounts to as much as 30.5° C.; soil temperatures decrease, and light intensities are enormously reduced. The change in mid-summer is most delightful.

Of the considerable amount of data recorded, only those dealing with the light intensities will be considered here. The prevailing trees at the first five stations are *Acer*, *Fagus*, and *Tsuga*. At the *Mnium* and *Taxus* stations *Acer spicatum* and *Acer pennsylvanicum* also occur. Under these, light intensities were extremely low; nevertheless at times the sun was able to send a few beams of direct sunlight into the deepest recesses. (Plate 2).

The reading in the *Pinus strobus* area showed a much greater light intensity and also much wider variations than at the other stations. The lowest reading taken on a bright day with light intensity in the open at 1 was .0625; on two other days it was .75. The table shows that similar variations in light intensities were found at all stations when the light in the open was 1. At the *Mnium* station under cover of trees and shrubs, the light was almost four times as strong on July 19 as it was on August 12.

Table IX shows very clearly that marked variations may occur in light intensities at the same station. This is due chiefly to a very discontinuous forest cover.

TABLE IX—LIGHT INTENSITIES NEAR BIG SPRINGS, DOUGLAS LAKE, MICHIGAN

		July 19	22	29	5	August 9	12
I	Open	1.0000	.2500	1.0000	.6666	.5000	1.0000
II	<i>Acer-Fagus-Tsuga</i>	.0083	.0133	.0083	.0083	.0033	.0022
III	<i>Acer-Fagus-Tsuga*</i>	.3333	.0625	.3750	.1250	.1666	.1666
IV	<i>Acer-Fagus-Tsuga</i>		.0166	.0333	.0277	.0222	.0277
V	<i>Taxus canadensis</i>	.0083	.0277	.0416	.0277	.0416	.0555
VI	<i>Mnium</i> sp.	.0083	.0055	.0083	.0083	.0083	.0022
VII	<i>Pinus strobus</i> ..	.0625	.1666	.7500	.1666	.1500	.7500
VIII	<i>Acer rubrum</i> ...	.0125	.0277	.0833	.0416	.0416	.0416

*The high light intensities at station III, located at the bottom of the park leading to the springs, as compared with stations II and IV, are due to a clearing.

In table X an attempt is made to show the effect of the forest cover on bright days as compared with cloudy days. Light in the open varied from .25 to 1. The light values in the open were figured as 1 in every case and the percentage of light at each station computed. These data sometimes are confusing rather than helpful. They conceal important differences in intensity. For example at the *Taxus* station the forest cover reduces the light intensity on July 22 to .0277, (Table IX), or it holds back 89 percent of the total daylight at that time. On August 12 the light intensity is .0555, and 94.5 percent of the total daylight has been held by the cover. Nevertheless the plants on August 12 have twice as much light for their development as they had on July 22.

TABLE X—REDUCTION IN LIGHT DUE TO VEGETATION EXPRESSED IN PERCENTAGE OF LIGHT IN THE OPEN. DATA GATHERED NEAR BIG SPRINGS, DOUGLAS LAKE, MICHIGAN

Date	19	July 22	29	5	August 9	12
Actual reading in open ..	1.	.25	1.	.6666	.5	1.
Reduction in percentage by shading	Percent	Percent	Percent	Percent	Percent	Percent
I Open	0	0	0	0	0	0
II <i>Acer-Fagus-Tsuga</i> ..	99.2	96	99.2	99.8	99.4	99.8
III <i>Acer-Fagus-Tsuga</i> ..	66	75	62.5	82.3	66.4	83.4
IV <i>Acer-Fagus-Tsuga</i> ..		93.4	96.7	95.9	95.6	97.3
V <i>Taxus canadensis</i> .	99.2	89	95.9	95.9	91.7	94.5
VI <i>Mnium</i> sp.	99.2	97.8	99.2	99.8	99.6	99.2
VIII <i>Pinus strobus</i>	93.7	33.3	25	75.1	97	75
IX <i>Acer rubrum</i>	96.2	89	92.7	93.8	91.7	95.9

Only a few data are available for studying the effect of forest on light intensities as they vary from hour to hour with the changing of the sun. Two cases are cited by way of example, but since in these trials it was not possible to take simultaneous readings, an unavoidable source of error was introduced. Four readings taken an hour apart under an *Acer-Fagus-Tsuga* cover show that the crowns cut off 60, 93, and 81 percents of light respectively. These figures represent a variation in light intensities of from .0166 to .3000. At the time of the latter intensities, the numerous seedlings of *Acer* and *Tsuga* had a sufficient light for all purposes. In an adjacent stand of *Tsuga*, the morning readings were 94 and 95 percents, which show a fairly uniform cover for that period. (Plate IV).

Numerous seedlings of *Fagus* and *Acer* were found in habitats the light intensities of which were .0250 and even lower. That higher light intensities with proper moisture conditions are favorable for

their development, can be seen by a comparison of the reproduction in deserted road-beds with that of adjacent areas. These wood-roads receive the full sunlight for a few hours at least on each bright day. *Acer* seedlings which cover the roadway are as thick as if grown in a seed-bed, whereas very few are found in the woods three rods away where the light was much weaker and root competition with the old stand of trees was more intense. (Plate III).

The data presented emphasize the fact that in the natural woods variations may occur in the amount of light available for seedlings, that in other words the intensity of the forest shade is an extremely variable factor. (Plate V).

3. BURLINGTON

In order to determine the relation of crown cover to the surface of the forest, a series of studies was started in definite areas. These areas were 100x100 feet and were subdivided into 100 squares, each 10x10 feet, the boundaries being marked with common wrapping cord. Then a map of the area was made, locating the size and kind of each individual tree, after which the crown was projected upon the ground and mapped. In some instances shrubs and herbaceous forms also were shown.

These maps and the data previously given show that there is considerable variation in the amount of light reaching the surface under a forest. The attempt was made now to determine the total light that would fall on a group of seedlings during the day, but in view of the lack of satisfactory self-recording instruments this was found to be a very difficult problem. The most satisfactory way seemed to be to determine as accurately as possible by the use of a camera how much light fell on a given point, a method which has been suggested by Frederick (6), but has not been used to any great extent. With the camera located at one and the same point, eight 5x7 plate exposures were made in the college woods on August 3, 1912, beginning at 2 P. M. The camera was pointed successively due east, southeast, south, southwest, west, upward with an eastern angle, directly upward and, finally, upward with a western angle. The first five exposures were meant in a way to follow the course of the sun across the sky. Velox prints were made and the light patches removed, as nearly as this was possible. In some instances it was necessary to estimate the amount to be cut out because of the fine branches and leaves.

The data are given in table XI.

TABLE XI—LIGHT DATA TAKEN IN THE COLLEGE WOODS BY USE OF CAMERA

	Original weight of paper grams	Final weight of paper grams	Shade percentage	Light percentage
East	2.970	2.690	90	10
Southeast	3.046	2.400	78	22
South	3.021	2.221	73	27
Southwest	3.062	2.370	77	23
West	3.038	2.801	92	8
Upwards eastern angle	2.885	2.395	83	17
Upwards	3.136	2.160	68	32
Upwards western angle	3.067	2.580	84	16

These figures show that during the day a considerable amount of light penetrates to the ground cover, despite the fact that the forest cover eliminates a large percentage. They also show how useless it is to attempt in such a place as a forest to determine available light for seedlings by means of isolated readings.

The photometer readings for the station near this location for the summer gave an average light value of only .0554 above some small white pines and .0374 below these pines. Table XII displays the average of a large number of readings taken in the natural forests of *Pinus strobus* or *Tsuga* near Burlington, together with reproduction statements.

TABLE XII—AVERAGE OF READINGS NEAR BURLINGTON

Location	Light intensity	Seedlings
Williston		
Pasture	.6766	none
Forest	.0266	none
Burlington, forest chiefly <i>Pinus strobus</i>		
Level ground	.0154	many
Level ground, above 3-foot seedlings	.0554	
Level ground, under 3-foot seedlings	.0374	some
South slope	.0278	none
North slope, above herbaceous plants	.0364	
North slope, under herbaceous plants	.0069	many
West slope	.0246	none
East slope	.0088	none

The data in table XII show no marked relationship between light intensities and the presence of seedlings. At one station the average reading was only .0069, yet the ground was well covered with seedlings whereas none grew at a nearby station where the light intensity was .0088 or a quarter greater. Seedlings were growing in this woods at

stations where light intensities were .0374, .0069 and .0154; but none grew at adjacent points where light intensities were .0278, .0246 and .0088.

A study of the foregoing tables soon convinces one that the present methods of determining light values in the forest are unsatisfactory. Too little attention has been paid to the fact that the so-called shade is a discontinuous shade and a constantly changing factor. The variations in light intensity due to clouds, the impossibility of making equal exposures in repeated readings, the variability of the forest cover thus requiring the operator to choose a "typical station for the forest under consideration," and the habit of reading only on bright days about noon; all these make for inaccuracy and emphasize the difficulty, if not impossibility, of determining the relation of forest trees to light by a "study in the forests."

The results of the work in the forests showed the necessity of devising a habitat wherein continuous shade may occur. Accordingly a series of frames was made of 1x1 inch lumber, each frame being two inches larger than the one preceding it in the stack. The smallest frame was 18 inches square. The larger frames were somewhat bulky, but by using iron braces at the angles a sufficient rigidity was preserved. Seven of these frames were covered with white cheesecloth, 36 threads to the inch, and several with similar cloth which had been dyed black.

A ditch large enough to admit the arm of the operator was dug under the north side of the frame or frames. When his arm was in place with the photometer under the covers, a black cloth was packed around it completely filling the space between the arm and the ditch to keep out all light from entering around the arm. While a reading was being made under the shades, a second operator made a simultaneous reading in the open. When several covers were used a long time exposure was found necessary, and two or more readings were made in the open to compare with the reading under the covers, thus taking cognizance of possible changes in total light which might occur during the interior exposure. Readings were taken on both clear and cloudy days. Table XIII may be taken as a sample. It displays a series of readings taken between 12 and 12:35 on August 16, 1912, when the sky was cloudless and the light in the open was 1.



PLATE IV. Discontinuous shade in a dense stand of hemlock near Douglas Lake, Michigan.



PLATE V. View in maple, beech, hemlock stand near Douglas Lake, Michigan.

TABLE XIII—LIGHT INTENSITIES IN CONTINUOUS SHADE PRODUCED BY CHEESE-CLOTH COVERS ON A CLEAR DAY

In the open	Light Intensities	Number of white covers	In the shade
1		1	.4000
1		2	.2220
1		3	.1666
1		4	.1250
1		5	.0833
1		6	.0625
1		7	.0500

Similar data to that in the last table are displayed in table XIV, except that the readings were taken on a cloudy day between 12:04 and 12:26 M. August 14, 1912.

TABLE XIV—LIGHT INTENSITIES IN CONTINUOUS SHADE PRODUCED BY CHEEEECLOTH COVERS ON A CLOUDY DAY

In the open	Light Intensities	Number of white covers	In the shade
.4999		1	.2222
.4333		2	.1333
.5666		3	.0833
.5666		4	.0555
.4333		5	.0417
.4999		6	.0333

A continuous shade of any desired percent of total light, within certain limits, can be maintained during the entire experimental period. In this shade a series of trials was conducted to determine the minimum light intensity at which white pine, balsam fir, and hemlock seedlings could produce starch, the plants being grown under the screens. It was found that when the light intensity was so far reduced as to register .0266, no starch whatever could be detected in the leaves in the white pine. The hemlock seemed to reach its minimum at about .005. No starch could be found in plants from under two black and four white screens, whereas traces of starch were found in these plants under one black and seven white screens with the same light intensity. These trials are being continued using several more varieties.

It is becoming increasingly evident that the relation of forest tree growth to the light environment can be solved only by carefully planned and executed experiments in the greenhouse and nursery where it is possible, to some extent at least, to control the factors influencing plant growth. We cannot hope that much new information will be obtained concerning this intricate subject by "a study of light in the forest."

The writer has under observation one-year-old seedling trees of white pine which grew in the summers of 1914 and 1915 under large cheesecloth shades which reduces the light approximately to the values shown in tables XIII and XIV. One set was transplanted to give each tree space for the development of its root system; the other set was left as they came up after broadcast sowing.

A comparison of the size, color and general vigor of the two sets seems to indicate beyond a doubt that the chief factor of the slow development of the latter set is not lack of light but some other factor, possibly root competition for water and food in the soil.¹

CONCLUSIONS

1. The word "tolerance" should be stricken from the vocabulary of forestry students unless to it can be accorded a more comprehensive definition. It is taken generally to express a light relationship, but really it expresses not a light relationship, but the total relationship of a tree to all factors of the habitat.

2. The filtered light in the forest has little value as a means of decomposition of carbon dioxide; the important light in the forest is weakened white light.

3. Light intensity data thus far published in forest light studies as a rule are averages of many readings, usually taken without reference to check readings in the open. They have been taken commonly on clear days about noontime and consequently readings usually are too high. Furthermore, the fact that shade in the forest is discontinuous is additional evidence of the untrustworthiness of much of the published data.

4. The relation of tree growth to light as an influencing factor can be determined only by controlled greenhouses and nursery trials. Light readings in the forest are of little value.

¹The writer is well aware of the fact that these cheesecloth shades have a decided influence upon all factors of this artificial habitat. Continuous records of changes in humidity, air and soil temperatures were taken during the season. Rainfall, soil moisture, and evaporation data were also collected. These figures will be published after further experimental data are available.

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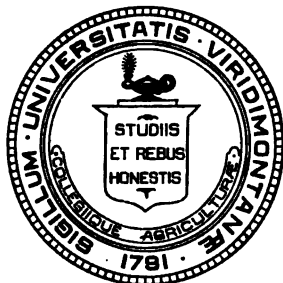
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MARCH, 1916

BULLETIN 194

University of Vermont and State Agricultural College
Vermont Agricultural Experiment Station
BURLINGTON, VERMONT

THE TREES OF VERMONT

by G. P. BURNS and C. H. OTIS



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University farm and buildings are on the Williston road, adjoining the University grounds on the east.



Photo by H. F. Perkins.

**A NATURAL GROUP OF WHITE PINE ON THE GROUNDS OF THE
UNIVERSITY OF VERMONT.**

for revision. Done. 1913
BULLETIN 194: THE TREES OF VERMONT

BY G. P. BURNS AND C. H. OTIS¹

INTRODUCTION

The supply of bulletin 73, entitled "The Trees of Vermont," has been exhausted for several years. Repeated calls from all parts of the State and especially from the schools make it evident that its revision and reissue would be welcomed.

The present publication represents a revision of Bulletin 73 of the Vermont Agricultural Experiment Station, issued in 1899, and of Bulletin 16, Vol. XIV, N. S., of the University of Michigan, issued in 1913 under the authorship of the junior writer². In the preparation of the present bulletin the authors have followed largely the general scheme and arrangement of the Michigan publication. Two chapters, "How to Study the Trees" and "Artificial Keys, How Made and Used," except for a few minor changes, are from the Michigan bulletin. The artificial keys for identification and the manual of trees have been adapted to the slightly different Vermont conditions. Most of the reproductions published in this bulletin have been made from new plates photographed from the drawings originally used to illustrate the Michigan bulletin. Credit has been indicated in each case. Finally, there have been added a series of bark photographs by the senior author, while the junior has contributed four original plates of drawings and accompanying descriptions and a section dealing with the identification and structure of Vermont woods. Upon the senior author has devolved the final bringing together of the component parts and the necessary editorial work involved.

This bulletin is intended primarily for the use of pupils in our public schools and of persons not especially trained in botany. For this reason the use of technical terms has been avoided whenever possible. In several cases such terms were necessary, but with the help of the glossary (page 233) their meaning can be easily understood.

The order of arrangement and nomenclature are essentially those of Gray's Manual. Following a tendency which is steadily gaining favor, all species names are printed with a small letter, regardless of their origin.

¹ Professor Otis, formerly curator of the botanical garden and arboretum of the University of Michigan, spent several months during the past year at this institution, collaborating with the senior author in the preparation of this bulletin.
² The authors take this occasion to express their appreciation of the courtesy of the University of Michigan authorities in allowing them to make such liberal use of the material from the former bulletin in their present work.

Two sets of keys are given. One is based upon characters which are present during the summer; the other uses the winter characters as a basis for identification.

Photographs have not been used as illustrations because they are too indefinite and give all characters equal emphasis. This generally conceals the essential marks necessary for identification and affords little help to the student. Accurate line drawings are substituted for photographs, since they have proved to be much more serviceable in classwork.

It is believed that with the aid of the drawings and descriptions given in this bulletin any person will be able to identify any Vermont tree. If, however, difficulty is found in naming a given tree, specimens of flowers, fruit, leaves, wood, etc., mailed to the Extension Service, Burlington, Vermont, will be named without charge, if of such a character and received in such condition as will admit of identification.

HOW TO STUDY THE TREES

Trees are such familiar objects that the people who dwell in nearly every portion of this country see them daily. Trees give cooling shade in our parks and dooryards and along our highways; they lend their beauty to the landscape and relieve it of monotony; they yield many kinds of fruits, some of which furnish man and the animals of the forest with food; and they furnish vast quantities of lumber for a multitude of uses. It is important then that every person, whether in the schools or beyond school age, should become acquainted with our trees. Most people know a few of the more common trees but are ignorant of the great wealth of trees of various kinds about them. Some persons who may have wished to learn more have been hindered for lack of a teacher and others have been dismayed by the very multitude of manuals to which they have had access.

In beginning a study of trees the student should be careful to confine himself to well established facts. Once started he should proceed slowly, assimilating each new discovery before seeking another. He should begin with the trees nearest home and then becoming familiar with these in all their aspects, he should extend his trips afield. Not only should he be able to name the trees when they are fully clothed in summer garb, but he should know as readily the same trees when only the bare branches stand silhouetted against the sky if he desires to gain a thorough knowledge of his subject.

The characters which are used in studying the trees are habits, leaves, flowers, fruits, buds, bark, distribution and habitat. These will be discussed briefly in the next few pages, the same order that is used in the detailed descriptions of species being maintained in the present discussion. A few drawings also will be added to make certain points clear and to show comparative forms.

NAME.—Every tree has one or several common names and a scientific or Latin name. Some of these common names are merely local, while others have a more extended use. A few names apply to totally different species. Thus, cottonwood in Vermont is *Populus deltoides*, in Idaho and Colorado *Populus angustifolia*, in California *Populus fremontii* and in Kentucky *Tilia heterophylla*. While it should not be forgotten that in common speech it is proper as well as convenient to call trees by their common names, yet, in view of the many uncertainties pertaining to their use, a scientific name at times is absolutely essential to the clear understanding of what is meant. Latin is the language in universal use by all scientists. No longer used by any civilized nation, it has become a dead language and consequently never changes. Its vocabulary and its constructions a thousand years hence will probably be the same that they are today. Being in universal use among scientists of all nationalities no confusion arises from the use of a Latin word. The oak in Germany is known as *Eiche*, in France as *chêne* and in Spain as *roble*, but the Latin word *Quercus* is the same in all these countries.

A scientific name as applied to trees consists at least of two parts, as *Quercus alba*. The first is the genus name and always is written with a capital letter, the second is the species name and is written with a small letter, the two names constituting the briefest possible description of the particular tree. It is customary to add to these the name or an abbreviation of the name of the person who first gave the name to the tree, as *Quercus alba* L., the abbreviation standing for Linnaeus. Sometimes a third name is used, as *Acer saccharum nigrum*, referring in this instance to a variety of the ordinary Sugar Maple. In some cases trees have more than one Latin name. When this is true the synonym or synonyms are placed in brackets after the accepted name.

Genera which bear a relationship to each other are placed in the same family, the family name always having the characteristic ending—*aceae*. Related families again are grouped into orders, with the characteristic ending—*ales*. Orders in like manner are arranged into larger groups, called classes, and the latter into still larger groups, divisions,

etc., each with its characteristic ending. Thus, *Acer saccharum nigrum* (Michx. f.) Britt. is classified as follows:

Division—Spermatophyta

Subdivision—Angiospermae

Class—Dicotyledoneae

Order—Sapindales

Family—Aceraceae

Genus—Acer

Species—saccharum

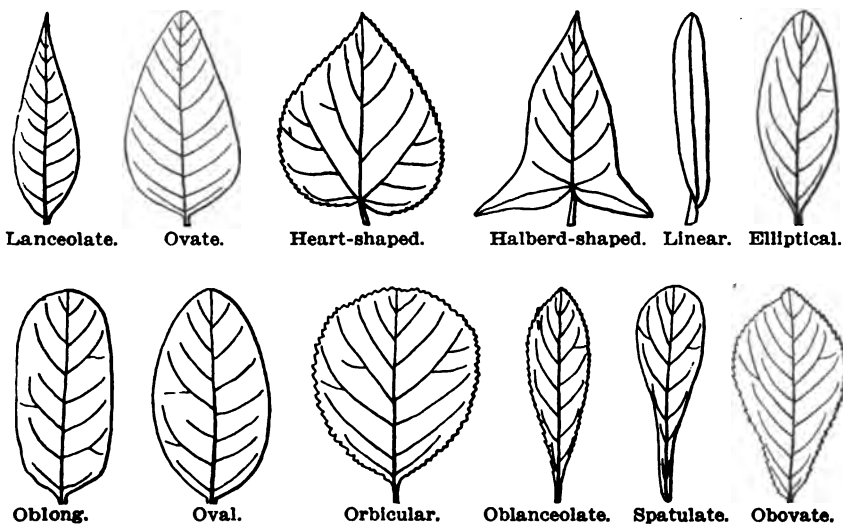
Variety—nigrum.

HABIT.—Habit, or the general appearance of a plant, is an important character of identification, especially as we become more and more familiar with the trees. Two main types are recognized, based on the manner of the branching of the trunk, the upright and the spreading. In the one the trunk extends straight upwards without dividing, as is typical in most of the conifers; in the other the trunk divides to form several large branches and the broad, spreading crown of most of our broad-leaf trees. In either case the crown may be regular in outline or very irregular, straggling or straight-limbed. Moreover, the tree growing in the open, where there is no crowding and plenty of light, may differ greatly from the tree in the forest, where the struggle for existence becomes very keen. A short, thick trunk and a low, spreading, many-branched crown characterize the tree in the open, whereas the forest tree has a long, slender, clean trunk and a narrow crown of few branches. In the descriptions of trees in this bulletin, unless otherwise stated, the habit in the open is the one given. Again, the tree may have been injured by storm or insect at some period of its growth and its natural symmetry destroyed. Moreover, the age of a tree has a great influence on its outline, young trees generally being narrow and more or less conical, broadening out as they become older. We may say, then, that each tree has an individuality of its own, little eccentricities similar to those that make people different from one another. And just as we have little difficulty in recognizing our friends at a distance by some peculiarity of walk or action, so we are able to recognize many trees at a distance by some peculiarity of form or habit.

LEAVES.—With the advent of spring the buds of our broad-leaf trees swell and burst and the leaves come forth and clothe the trees with mantles of green, hiding the branches which have been bare through the cold winter months. The evergreens, too, take on fresh color and commence a new period of growth. The beginner in botani-

cal study finds the leaves the most interesting portion of a tree and one which affords him a ready means of identification. It must be re-

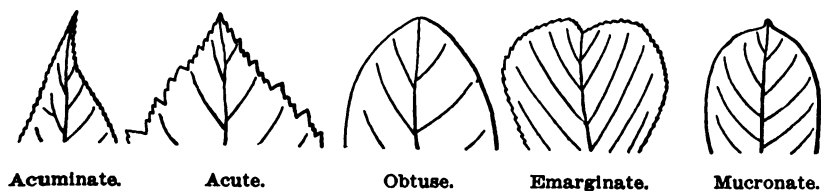
I. LEAF OUTLINES



membered, however, that leaves vary greatly in size, shape and general appearance. For example, the leaves on a flourishing sprout are usually relatively large, whereas they may be much smaller on a stunted tree of the same species growing nearby and subjected to adverse circumstances.

The leaves of a big white oak standing in the yard may be hardly lobed on the lowermost branches, while higher up they are deeply cut.

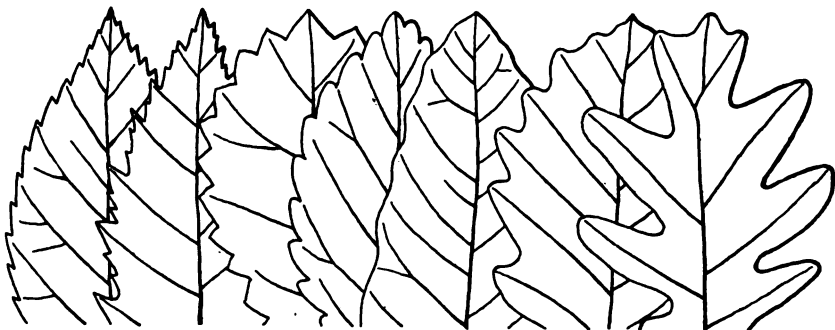
II. LEAF TIPS



However, in spite of the many modifications they undergo, the leaves of any one species have certain rather constant characteristics which are found in all forms, and the student who has once learned what these are will have little difficulty in selecting and recognizing typical specimens.

Leaves are either persistent, as in most of our conifers, which remain green all winter, or they assume various colors with the coming of the frost, and drop to the ground early in autumn although often they hang dead and lifeless far into the winter. The characteristics of leaves which we are accustomed to consider in determining their rela-

III. LEAF MARGINS



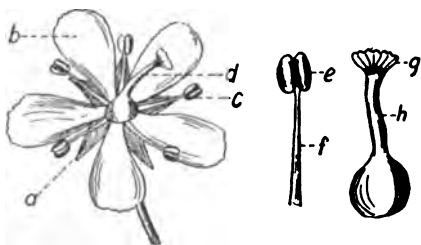
Serrate. Doubly Serrate. Dentate. Crenate. Undulate. Sinuate. Lobed.

tionships are their position or arrangement on the branch, whether simple or compound, size, shape, texture, color, the amount and character of pubescence, the character of the margin, venation, etc. The following diagrams will serve to illustrate some of the ordinary forms and shapes of leaves, their margins, etc.

FLOWERS.—Every tree when old enough bears flowers in its proper season. Some of these, as the hawthorns, locusts and horse-chestnuts,

are very showy; others, like the oaks and hickories, are comparatively inconspicuous. Some are brilliantly colored, while others are of the same color as the leaves. Nevertheless, the flowers are very accurate means of classification, and the only drawback to their use for this purpose is the fact that they last for such a little while each year.

IV. PARTS OF A FLOWER



Perfect Flower.

Stamen. Pistil.

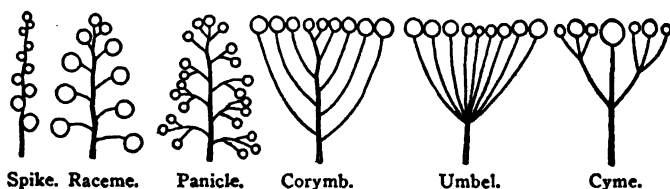
- a. Sepal (Calyx).
- b. Petal (Corolla).
- c. Stamen.
- d. Pistil.
- e. Anther.

- f. Filament.
- g. Stigma.
- h. Style.
- i. Ovary.

Just as there are male and female in the animal world, so the male and the female are found in the plant world. A few of our trees, as the locust, basswood and cherry, have perfect flowers, bearing both stamens and pistil. The

great majority, however, have unisexual flowers, bearing either stamens or pistils, but not both. When both male and female flowers are found on the same tree, the flowers are said to be monoecious, and when male flowers occur on one tree and the female on a different tree, the flowers are said to be dioecious. The cottonwood of New England is dioecious and each little seed is surrounded by a tuft of long, white hairs which enables the wind to carry it considerable distances from the parent tree, to the disgust of people living within its range. The planting of the cottonwood is forbidden within the bounds of several cities on account of this objection. Since it is desirable in some places to plant this rapidly growing tree, as in cities burning large amounts of soft

V. TYPES OF INFLORESCENCES



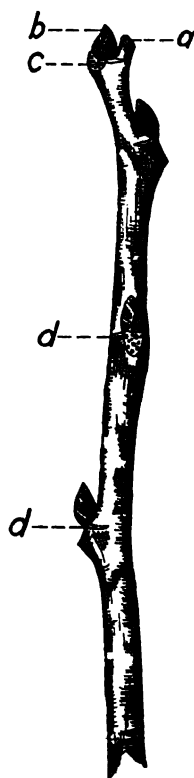
coal, it is a distinct advantage to know that the male trees may be planted safely, since they bear no seed and shed no "cotton."

Before trees can produce fruit their flowers must be fertilized, i. e., pollen from the anther of a stamen must come in contact with the stigma of a pistil. Some flowers are self-fertilized and others are cross-fertilized. For a long time it was not understood how fertilization was accomplished, but now we know that many insects, like the nectar-loving bees and butterflies, and in other instances the wind, transport the pollen from one flower to another, often miles being traversed before the right kind of flower or a flower in the right stage of development is found. And many are the modifications of flowers to insure this transference of pollen.

FRUIT.—So numerous and so varied are the forms of tree fruits that it would be only confusing to state their characters. Some fruits, such as the achenes of the poplars and willows, are so small and light that they are carried long distances by the wind; others, like the hickory nuts and walnuts, are too heavy to be wind-blown. Many fruits are of considerable economic and commercial importance and are gathered and marketed on a large scale. Among these are the hickory nuts, walnuts, chestnuts, etc. Some, not esteemed by man,

form an important article of diet for the birds and small animals of the forest. Unfortunately there are a number of limitations to the usefulness of fruit for identification purposes. Some trees require years to mature their fruit. Many trees, while producing an abundance of fruit at certain intervals, bear none at all or only very small and uncertain quantities between the years of abundance. Again, in the case of dioecious trees, only the female or pistillate bear fruit. Notwithstanding these limitations tree fruits are a very valuable aid to the student, and he should always search closely for evidences of their presence and character.

VI. WINTER TWIG
OF RED MULBERRY



- a. Tip-scar.
- b. Lateral bud.
- c. Leaf-scar.
- d. Stipule-scars.

the forest. Unfortunately there are a number of limitations to the usefulness of fruit for identification purposes. Some trees require years to mature their fruit. Many trees, while producing an abundance of fruit at certain intervals, bear none at all or only very small and uncertain quantities between the years of abundance. Again, in the case of dioecious trees, only the female or pistillate bear fruit. Notwithstanding these limitations tree fruits are a very valuable aid to the student, and he should always search closely for evidences of their presence and character.

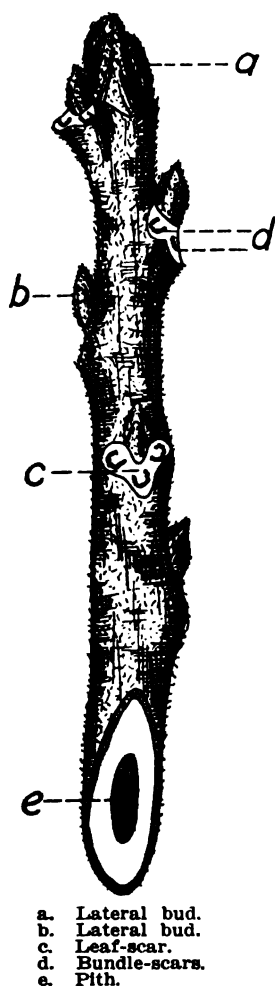
WINTER-BUDS.—Buds, with their accompanying leaf- and stipule-scars, form the basis of tree identification in winter. The size, color, position with reference to the twig, number and arrangement and character of bud-scales, etc., all are characters of the greatest value in winter determinations. Buds either are terminal or lateral, depending on their position on the twig. A lateral bud is one situated on the side of a twig in the axil of a leaf-scar. A terminal bud is one situated at the end of a twig, where it is ready to continue the growth of the twig the following spring. To the presence or absence of the terminal bud is accorded much importance in the keys on pages 162 and 163, which enable

one more surely to identify a tree. Inasmuch as the determination of this point gives the beginner some trouble at first, it is hoped that the accompanying diagrams and explanatory remarks will serve to make the distinction clear.

In the elms, willows, basswood and many other species the terminal bud and a small portion of the tip of the twig dies and drops off in late autumn, leaving a small scar at the end of the twig (a, fig. VI). The presence of this tip-scar indicates that the terminal bud is absent. Often a lateral bud will be found very close to the tip-scar (b, fig. VI), which, bending into line with the twig, makes it appear to be a terminal rather than a lateral bud. However, the presence of a leaf-scar immediately below it shows it to be a lateral bud (c, fig. VI). The

unaided eye can discern the tip-scars on some of the larger twigs, but a hand lens will be found necessary when the smaller twigs are under observation.

VII. WINTER TWIG OF BLACK WALNUT



The arrangement, size and shape of the leaf-scars (c, fig. VII) are important factors in identification by winter characters. Within the leaf-scars are one or more dots (d, fig. VII), sometimes quite inconspicuous, often very prominent. These are the scars left by the fibro-vascular bundles which run through the petiole into the blade of the leaf, and are designated as bundle-scars. There may be many as in the oaks, three as in the poplars and cherries, or only one as in tamarack and the spruces; and they may be arranged in a U- or V-shaped line, or they may be without definite order. Often stipule-scars (d, fig. VI) occur on either side of the leaf-scar and are caused by the fall of a pair of small leaflets called stipules, located at the base of the leaves. Their form varies according to the form of the stipules which made them

BARK.—The woodsman uses the bark more than any other feature in identifying trees, and often he is able in this manner to distinguish trees with much accuracy at great distances. However, the appearance of bark differs so greatly with the age of the tree and with its environment that it is difficult to describe it accurately. Some characters are distinctive, however, and serve as a ready means of identification; as for example the peeling of the sycamore and paper

birch, the “shelling” of the shellbark hickory and the mucilaginous inner bark of the slippery elm.

WOOD.—Under this heading are exhibited some of the general characteristics of wood. While it is not expected that this information will be of any particular value to the student of tree botany in identifying living trees, it happens often that such a one finds himself in the

midst of felling operations or in the lumberyards; and under such circumstances a knowledge of the wood characters may be of considerable value. Few, if any, manuals or bulletins have been published dealing in a simple but comprehensive manner with the structure of wood. Especially is this true of the photographs or drawings accompanying such works. It hardly comes within the scope of this bulletin to discuss in detail all the woods of all the tree species growing in Vermont, although such a study doubtless would be worth while. Yet there does seem to be an urgent demand for such a publication dealing with our more common trees; and hence a detailed study has been made of such of our woods as are of importance from a lumbering standpoint. Illustrations, showing cross-, radial- and tangential-sections, accompanied by descriptions and keys, have been brought together in a chapter at the end of the manual proper, to which are referred persons desirous of a more thorough acquaintance with our commercial woods.

DISTRIBUTION AND HABITAT.—To a lesser extent do distribution and habitat of a species aid in the identification of a tree. It is a distinct advantage to know that the wild plum is native in western Vermont only and that the black gum is limited to the southernmost portions of the state. So, too, knowing the water-loving habit of the swamp spruce, we would not expect to find it flourishing on a rocky mountain-top.

The characteristics, then, which are used to identify the trees about us are many. Not all will be available at any one time, and not all have been mentioned in the foregoing pages nor in the manual. It is our opinion, however, that the student will not be handicapped greatly by this lack of detail, but rather that he will take great interest and genuine pleasure in discovering these things for himself.

ARTIFICIAL KEYS, HOW MADE AND USED

An artificial key is a scheme for identifying any unknown object under consideration easily and quickly. This bulletin being devoted to the trees of Vermont, its keys are intended to make it possible for any person, even if his botanical training be meager, to determine what native trees grow about his home or farm or in any Vermont city park or woodlot. With certain modifications and within limitations they may prove useful in other localities as well.

Since many people are unfamiliar with the construction and use of keys for purposes of identification, it is the purpose of the following paragraphs briefly to outline the principles upon which they are built and the manner in which they are used.

The keys are based on the most striking similarities and differences manifested by the various parts of trees—twigs, buds, leaves, etc.—that is to say, those characters which stand out in bold relief, which catch the eye at first sight. Two alternatives are presented, either a character *is* or *is not* presented; these are the only choices possible. Indeed, further divisions are unnecessary and lead only to confusion and possible oversight. The two diametrically opposed characters are said to be coordinate in rank. In the keys they are preceded by the same letter or letters (*a* and *aa* or *b* and *bb*, etc.) and are set at the same distance from the left margin of the page. Often *a* and *aa*, or *b* and *bb* are divisible further into other groups; in every case the characters are opposed (a positive and a negative) and are given coordinate rank. It is desirable for mechanical reasons to divide the main divisions of the key more or less evenly, but this is not always feasible, nor should it be adhered to strictly.

The nature and use of a key may be made the more clear by a homely but concrete example. Let us suppose that it is desired to construct a key in order to distinguish from one another five houses in a city block. Three of these houses are built of wood, two of brick, and of the three wooden houses two are painted white and one brown. We may classify them as follows:

- a.* Houses wood.
 - b.* Body paint brown *Smith's house*
 - bb.* Body paint white.
 - c.* Trimmings green color *Jones' house*
 - cc.* Trimmings slate color *Brown's house*
- aa.* Houses brick.
 - b.* Roof gray slate *Johnson's house*
 - bb.* Roof red tile *Public library*

It is desirable in many instances to add other characters to lessen the likelihood of confusion, in cases where the characters chosen are not distinct, and in order to show the user that he is on the right track. Thus, in the example just given, green color and slate color might be confused owing to certain defects of the eye, to a coating of dust or deficiencies of the light. Hence we would be justified in adding to the above statements additional distinguishing characteristics. Thus:

bb.

- c.* Trimmings green color; gable roof.....*Jones' house*
- cc.* Trimmings slate color; mansard roof.....*Brown's house*

The keys in this bulletin are constructed on these principles. They are not always as simple as the illustration just used, but if the reader has mastered the house illustration he will have little or no trouble with the larger keys. In order that the usage of the keys may be made the more clear, the following example, couched in language using the personal pronoun, is set forth at some length. The reader is advised to trace it from beginning to end as a ready means of familiarizing himself with the use of and possibilities of the key system.

Suppose that during a summer stroll you come across a large tree with rough, flaky bark and thin, lobed leaves which you do not know. Turning to the *Summer Key to the Genera* on pages 16 to 19, you find first *a Leaves simple*, and contrasted with this *aa Leaves compound*. Obviously the leaf is simple and the genus sought lies in that portion of the key preceding *aa*, i. e., under *a*. The subdivisions, *b*, and *bb*, under *a* afford you a choice between *Leaves needle-shaped, awl-shaped, strap-shaped or scale-like* and *Leaves broad and flat*. The leaf being broad and flat you pass onwards in the key to *c* and *cc* under *bb*. Here you have a choice between *Leaves alternate or clustered* and *Leaves opposite*. Inspection shows the arrangement to be alternate, and you know that the genus sought lies in that portion of the key which lies between *c* and *cc*. Passing to *d* and *dd* under *c* you are offered the choice between *Margin of leaves entire or only slightly undulate* and *Margin of leaves serrate, toothed or lobed* and your observation clearly indicates that the leaf is neither entire nor undulate, hence are in *dd* class. Under *dd* you may choose between *e, Margin of leaves serrate to toothed* and *ee, Margin of leaves distinctly lobed*. The leaf being deeply lobed, you know that the genus sought is one of five lying between *ee* and *cc*, all of which have lobed leaves. To make the determination, you must look for the fruit, since *f* and *ff* under *ee* give a

choice between *Fruit an acorn* and *Fruit not an acorn*. You poke about in the grass beneath the tree with your foot, finding an acorn, water-soaked and worm-eaten, and then another. But these may have been carried hither by an industrious squirrel or washed here by the rain or blown by the wind and deposited for the entrapment of the unwary. Hence you look up into the tree for affirmation and observing more closely than heretofore you note that the young, green acorns are quite apparent. The genus, then, is *Quercus*.

Before going further in your pursuit it will be well for you to go back over the key to make careful note of the particular characters which were used to separate this genus from the other genera and to try to fix these in mind. This being done, you should turn to the page indicated, where you will find a *Summer Key to the Species of Quercus*. You may then run through this key in the same manner that you did the genus key. If you have been careful in your search you will stop finally at *Quercus alba*. At this point you will do well once more to pause and go back over this key and try to fix in mind the characters which were used to separate the various species, especially the difference between your tree and *Quercus macrocarpa*, which it resembles so closely. This done, you will turn to the page indicated and compare the characters of your tree with the drawings and descriptions. If you are satisfied with your diagnosis, well and good. If you find that you are wrong, go over the keys again and find wherein you were led astray.

Before you leave the tree take a sample of leaf properly labeled which you can press between the pages of an old magazine and save for future reference. Do this with other trees which you may find and when you get home lay them out side by side so that the labels will not show and compare them. A few trials of this kind will serve to form a mental picture of each leaf which you will remember.

A very helpful practice for the beginner is that of making keys based upon various characters. Practice keys of this kind will bring out the differences and likenesses of trees as will no other means, and characters which hitherto have escaped the eye will be brought forward prominently. Nor should the student take his characters from books, but rather should go to the woods and get his knowledge at first hand.

It is hardly necessary to state that while the key is a valuable crutch while learning to walk, once the leg is strong enough to bear the weight it should be discarded, lest it becomes a burden. A key's main function is the guidance of the student through the preliminary steps leading to a more intimate knowledge of the trees.

SUMMER KEY TO THE GENERA

- a. Leaves simple.
 - b. Leaves needle-shaped, awl-shaped, strap-shaped or scale-like.
 - c. Leaves in clusters of 2-many.
 - d. Leaves in clusters of 2-5 sheathed, persistent for several years **Pinus**, p. 25.
 - dd. Leaves in fascicles of 8-many, on short, lateral branchlets, deciduous in autumn..... **Larix**, p. 35.
 - cc. Leaves solitary, not clustered.
 - d. Leaves opposite.
 - e. Twigs flattened; leaves all of one kind, scale-like, decurrent on the stem; fruit a small, pale brown cone, **Thuja**, p. 51.
 - ee. Twigs essentially terete; leaves of two kinds, either scale-like, or else awl-shaped, often both kinds on the same branch, not decurrent on the stem; fruit berry-like, bluish **Juniperus**, p. 53.
 - dd. Leaves alternate or spirally-whorled.
 - e. Leaves flattened, soft to the touch.
 - f. Leaves $\frac{1}{2}$ - $1\frac{1}{4}$ inches long, sessile, aromatic; cones 2-4 inches long; bark of trunk with raised blisters containing resin **Abies**, p. 47.
 - ff. Leaves seldom over $\frac{1}{2}$ inch long, short-petioled, not aromatic; cones about $\frac{3}{4}$ inch long; bark of trunk without raised blisters **Tsuga**, p. 49.
 - ee. Leaves 4-sided, harsh to the touch..... **Picea**, p. 37.
 - bb. Leaves broad and flat.
 - c. Leaves alternate or clustered, never opposite.
 - d. Margin of leaves entire or only slightly undulate.
 - e. Leaves 2-5 inches long; fruit a drupe or berry, **Nyssa**, p. 183.
 - ee. Leaves 5-9 inches long; fruit an acorn.. **Quercus**, p. 112.
 - dd. Margin of leaves serrate, toothed or lobed.
 - e. Margin of leaves serrate to toothed.
 - f. Branches armed with stiff, sharp thorns, **Crataegus**, p. 147.

- ff. Branches not armed.
 - .g. Base of leaves decidedly oblique.
 - h. Leaf-blades about as long as they are broad, heart-shaped; fruit globose, woody, ripe in autumn,
Tilia, p. 181.
 - hh. Leaf-blades $1\frac{1}{2}$ -2 times as long as they are broad, oval to ovate; fruit a membranaceous samara, ripe in spring **Ulmus**, p. 129.
 - gg. Base of leaves essentially symmetrical.
 - h. Teeth coarse, 2-5 per inch of margin.
 - i. Leaves very glabrous both sides; fruit a prickly bur.
 - j. Leaves 3-5 inches long, very lustrous beneath; bark close, smooth, steel-gray. . . **Fagus**, p. 107.
 - jj. Leaves 6-8 inches long, not lustrous beneath; bark fissured, brownish. . . . **Castanea**, p. 108.
 - ii. Leaves pubescent or white-tomentose, at least beneath; fruit not a prickly bur.
 - j. Leaves 2-4 inches long, broadly ovate to sub-orbicular; fruit a very small capsule, falling in spring **Populus**, p. 60.
 - jj. Leaves 4-7 inches long, oblong-lanceolate to obovate; fruit an acorn, falling in autumn,
Quercus, p. 112.
 - hh. Teeth fine, 6-many per inch of margin.
 - i. Leaf-petioles laterally compressed; leaves tremulous **Populus**, p. 60.
 - ii. Leaf-petioles terete; leaves not tremulous.
 - j. Leaf-blades at least 3 times as long as they are broad.
 - k. Twigs brittle; fruit a very small capsule, falling in spring **Salix**, p. 55.
 - kk. Twigs tough; fruit a fleshy drupe, falling in late summer or autumn. . . . **Prunus**, p. 149.
 - jj. Leaf-blades not more than twice as long as they are broad.
 - k. Leaf-blades about twice as long as they are broad.
 - l. Margin of leaves singly serrate; fruit fleshy.

- m.* Lenticels conspicuous; pith whitish or brownish; bark easily peeled off in papery layers; buds ovoid,
Prunus, p. 149.
- mm.* Lenticels inconspicuous; pith greenish; bark not separable into papery layers; buds narrow-conical,
Amelanchier, p. 145.
- ll.* Margin of leaves doubly serrate; fruit not fleshy.
 - m.* Trunk fluted; fruit inclosed within a halberd-shaped involucre,
Carpinus, p. 95.
 - mm.* Trunk not fluted; fruit not inclosed within a halberd-shaped involucre.
 - n.* Bark of trunk gray-brown, broken into narrow, flattish pieces loose at the ends; fruit in hop-like strobiles,
Ostrya, p. 93.
 - nn.* Bark of trunk white, yellow or dark brown, platy or cleaving off in papery layers; fruit not in hop-like strobiles **Betula**, p. 97.
- kk.* Leaf-blades almost as broad as they are long.
 - l.* Lower side of leaves more or less downy; sap milky; leaves not crowded on short, spur-like branchlets; fruit berry-like, black **Morus**, p. 137.
 - ll.* Lower side of leaves glabrous; sap not milky; leaves crowded on short, spur-like branchlets; fruit a large, green pome,
Pyrus, p. 143.
- ee.* Margin of leaves distinctly lobed.
 - f.* Fruit an acorn..... **Quercus**, p. 112.
 - ff.* Fruit not an acorn.
 - g.* Leaf-lobes entire; leaves lustrous above, their petioles 5-6 inches long..... **Liriodendron**, p. 139.

- gg.* Leaf-lobes sinuate-toothed to serrate; leaves not lustrous above, their petioles 1-2 inches long.
- h.* Leaf-lobes coarsely sinuate-toothed; winter-buds forming in summer within the petiole of the leaf,
Platanus, p. 141.
- hh.* Leaf-lobes serrate; winter-buds not forming in summer within the petiole of the leaf.
- i.* Branches armed with stiff, sharp thorns; sap not milky **Crataegus**, p. 147.
- ii.* Branches unarmed; sap milky, ... **Morus**, p. 137.
- cc.* Leaves opposite **Acer**, p. 162.
- aa.* Leaves compound.
- b.* Leaves alternate.
- c.* Branchlets armed with short, sharp prickles.. **Robinia**, p. 159.
- cc.* Branchlets unarmed.
- d.* Upper leaflets less than 1 inch broad; fruit berry-like, $\frac{1}{4}$ inch in diameter **Pyrus**, p. 143.
- dd.* Upper leaflets 1-5 inches broad; fruit a nut an inch or more in diameter.
- e.* Leaflets 5-11; pith homogeneous..... **Carya**, p. 83.
- ee.* Leaflets 11-23; pith chambered..... **Juglans**, p. 77.
- bb.* Leaves opposite.
- c.* Leaves pinnately compound; fruit a samara.
- d.* Leaflets 3-5; samaras paired..... **Acer**, p. 162.
- dd.* Leaflets 7-11, exceptionally 5; samaras not paired,
Fraxinus, p. 185.
- c.* Leaves digitately compound; fruit a prickly bur,
Aesculus, p. 179.

WINTER KEY TO THE GENERA

- a. Leaves persistent and green through the winter, needle-shaped, awl-shaped or scale-like.
 - b. Leaves in clusters of 2-5, sheathed.....**Pinus**, p. 25.
 - bb. Leaves solitary, not clustered.
 - c. Leaves opposite.
 - d. Twigs flattened; leaves all of one kind, scale-like, decurrent on the stem; fruit a small pale brown cone..**Thuja**, p. 51.
 - dd. Twigs essentially terete; leaves of two kinds, either scale-like, or else awl-shaped, often both kinds on the same branch, not decurrent on the stem; fruit berry-like, bluish, **Juniperus**, p. 53.
 - cc. Leaves alternate or spirally-whorled.
 - d. Leaves flattened, soft to the touch.
 - e. Leaves $\frac{1}{2}$ -1 $\frac{1}{4}$ inches long, sessile, aromatic; cones 2-4 inches long; bark of trunk with raised blisters containing resin**Abies**, p. 47.
 - ee. Leaves seldom over $\frac{1}{2}$ inch long, short-petioled, not aromatic; cones about $\frac{3}{4}$ inch long; bark of trunk without raised blisters**Tsuga**, p. 49.
 - dd. Leaves 4-sided, harsh to the touch.....**Picea**, p. 37.
- aa. Leaves not persistent and green throughout the winter, but deciduous in early autumn.
 - b. Twigs, branches or trunks armed with stiff, sharp spines or thorns.
 - c. Thorns or spines not exceeding $\frac{1}{2}$ inch in length on the branches, in pairs at each node; buds rusty-hairy, 3-4 superposed; fruit a flat pod**Robinia**, p. 159.
 - cc. Thorns or spines much exceeding $\frac{1}{2}$ inch in length on the branches, not in pairs at each node; buds not rusty-hairy, not superposed; fruit a pome**Crataegus**, p. 147.
 - bb. Twigs, branches or trunks unarmed.
 - c. Leaf-scars mainly crowded on short, stout, lateral shoots; bundle-scar 1; fruit a cone**Larix**, p. 35.
 - cc. Leaf-scars distributed along the lateral branches; bundle-scars 3-many; fruit not a cone.
 - d. Leaf-scars 2 at a node, i. e., opposite.
 - e. Terminal buds $\frac{1}{2}$ -1 $\frac{1}{2}$ inches long, resin-coated; twigs very stout**Aesculus**, p. 179.

- ee.* Terminal buds rarely exceeding $\frac{1}{2}$ inch in length, not resin-coated; twigs not conspicuously stout.
- f.* Bundle-scars usually 3, distinct, separated. **Acer**, p. 163.
- ff.* Bundle-scars many, minute, more or less confluent in a U-shaped line **Fraxinus**, p. 185.
- dd.* Leaf-scars 1 at a node, i. e., alternate.
- e.* Bundle-scars 3 or in 3 compound, but distinct groups.
- f.* Terminal bud present.
- g.* Stipule-scars present.
 - h.* First scale of lateral bud directly in front, i. e., exactly above the center of the leaf-scar; twigs brittle; pith somewhat star-shaped in cross-section **Populus**, p. 61.
 - hh.* First scale of lateral bud not directly in front, i. e., to one side of the center of the leaf-scar; twigs not brittle; pith circular in cross-section,
 - Prunus**, p. 149.
- gg.* Stipule-scars absent.
 - h.* Buds bright to dark red, the terminal $\frac{1}{8}$ - $\frac{1}{4}$ inch long **Nyssa**, p. 183.
 - hh.* Buds brownish to gray, the terminal exceeding $\frac{1}{4}$ inch in length.
 - i.* Buds narrow-conical, sharp-pointed; leaf-scars small, narrowly crescent-shaped; twigs about $\frac{1}{16}$ inch thick; pith homogeneous; fruit berry-like, not present. **Amelanchier**, p. 145.
 - ii.* Buds broadly conical to ovoid, blunt-pointed; leaf-scars conspicuous, broadly heart-shaped; twigs about $\frac{1}{4}$ inch thick; pith chambered; fruit a nut, often present. **Juglans**, p. 77.
- ff.* Terminal bud absent (sometimes present on short shoots of *Betula*).
- g.* Stipule-scars present.
 - h.* Bud-scale only 1 visible; twigs brittle,
 - Salix**, p. 55.
 - hh.* Bud-scales 2 or more; twigs not brittle.
 - i.* Bark smooth, close, warty or peeling off in papery layers, but not flaky nor rough-ridged.
 - j.* Trunk fluted; catkins not present in winter; lenticels not elongated horizontally; low tree or bushy shrub **Carpinus**, p. 95.

- gg.* Terminal bud absent (occasionally present in *Castanea*).
- h.* Bud at end of twig very obliquely unsymmetrical, mucilaginous when chewed.....**Tilia**, p. 181.
- hh.* Bud at end of twig symmetrical, not mucilaginous when chewed.
- i.* Bud-scales 2-3 visible; pith star-shaped in cross-section; sap not milky; fruit a prickly bur, present; large tree**Castanea**, p. 108.
- ii.* Bud-scales 4-8 visible; pith not star-shaped in cross-section; sap milky; fruit berry-like, not present; small tree.....**Morus**, p. 137.

PINACEAE—PINE FAMILY

THE PINES

The pines are the largest and most useful group of trees included in the great cone-bearing family. There are nine different species in the eastern United States, four of which are found in Vermont.

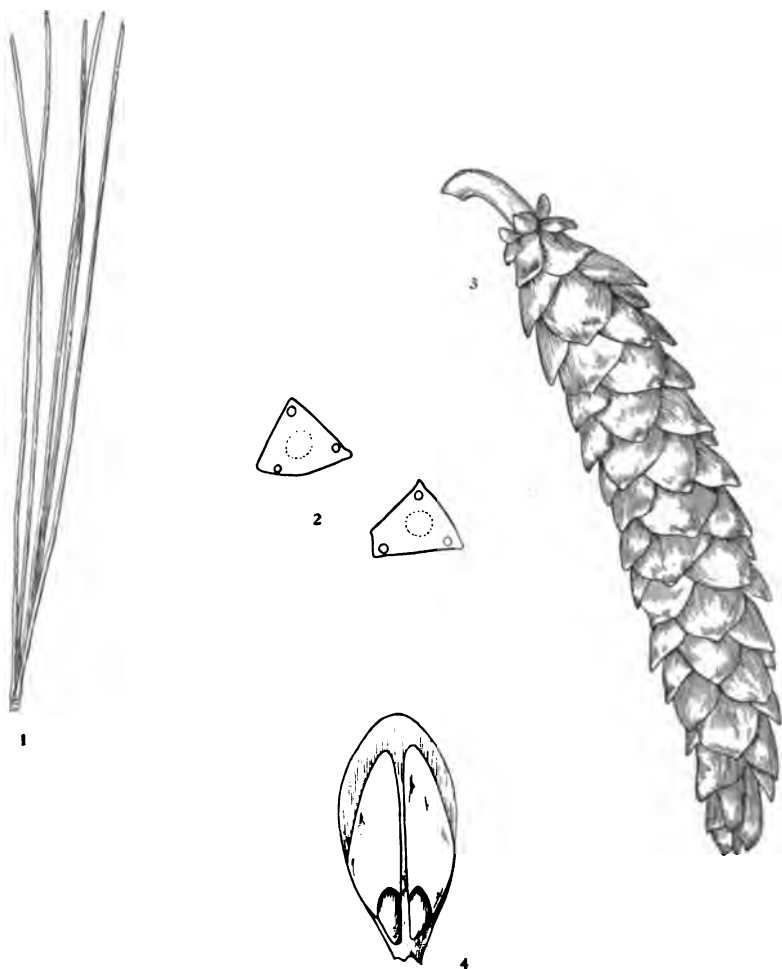
The pines, like the other members of this family, produce their seeds in cones. They are peculiar, however, in that their cones require two years for maturing. The flowers also take the form of cones, the pollen-bearing and the ovule-bearing clusters being separated, though both may be found on the same tree. The yellow pollen matures in May or June, when it is scattered in great abundance, to be borne to its destination by the wind. Most of the seed-bearing cones develop on the upper branches, and the nut-like seeds escape from them during the second autumn. The empty cones with opened scales thereafter may cling to the tree for some time or they may fall soon.

The leaves of all the evergreens cling to the branches several years. The leaves of the white pine, for example, drop when they are three or four years old. The arrangement of the leaves, or needles, in clusters of from two to five, with the base of each cluster encased in a delicate sheath, offers a simple means of distinguishing the species.

Introduced species.—Two European pines, the Austrian and the Scotch, are often planted in Vermont as forest trees as well as for ornamental purposes. The Scotch pine has leaves two in a cluster, 2-4 inches long, flat and of a bluish-white hue. The Austrian pine has dark green, slender, rigid leaves, two in a cluster, 4-6 inches long.

SUMMER AND WINTER KEY TO THE SPECIES OF PINUS

- a.* Leaves 5 in a cluster ; cones 4-10 inches long **P. strobus**, p. 27.
- aa.* Leaves not 5 in a cluster ; cones less than 4 inches long.
 - b.* Leaves 2 in a cluster ; cone-scales unarmed, or at most provided with minute prickles.
 - c.* Leaves less than 4 inches long (about 1 inch), strongly divergent ; cones pointing forward towards the tip of the branch, persistent 10-15 years, opening very unevenly,
 - P. banksiana**, p. 31.
 - cc.* Leaves 4-6 inches long, not strongly divergent ; cones not pointing forward towards the tip of the branch, not persistent 10-15 years, but opening in the autumn of the second season and falling the next summer **P. resinosa**, p. 33.
 - bb.* Leaves 3 in a cluster ; cone-scales armed with conspicuous prickles **P. rigida**, p. 29.

White Pine

(Mich. Trees).

1. Cluster of leaves, x 1.
2. Cross-sections of leaves, enlarged.
3. Partly opened cone, x $\frac{3}{4}$.
4. Cone-scale with seeds, x 1.

PINACEAE

White Pine

Pinus strobus L.

HABIT.—A large tree 60-80 feet high, with a trunk diameter of 2-4 feet; forming a wide, pyramidal crown. Formerly trees 100-150 feet in height and 5-7 feet in trunk diameter were not exceptional.

LEAVES.—In clusters of five; 3-5 inches long; slender, straight, needle-shaped, 3-sided, mucronate; pale blue-green. Persistent about 2 years.

FLOWERS.—June; monoecious; the staminate oval, light brown, about $\frac{1}{3}$ inch long, surrounded by 6-8 involucral bracts; the pistillate cylindrical, about $\frac{1}{4}$ inch long, pinkish purple, long-stalked.

FRUIT.—Autumn of second season, falling during the winter and succeeding spring; pendent, short-stalked, narrow-cylindrical, often curved, greenish cones, 4-10 inches long; scales rather loose, slightly thickened at the apex; seeds red-brown, $\frac{1}{4}$ inch long, with wings 1 inch long.

WINTER-BUDS.—Oblong-ovoid, sharp-pointed, yellow-brown, $\frac{1}{4}$ - $\frac{1}{2}$ inch long.

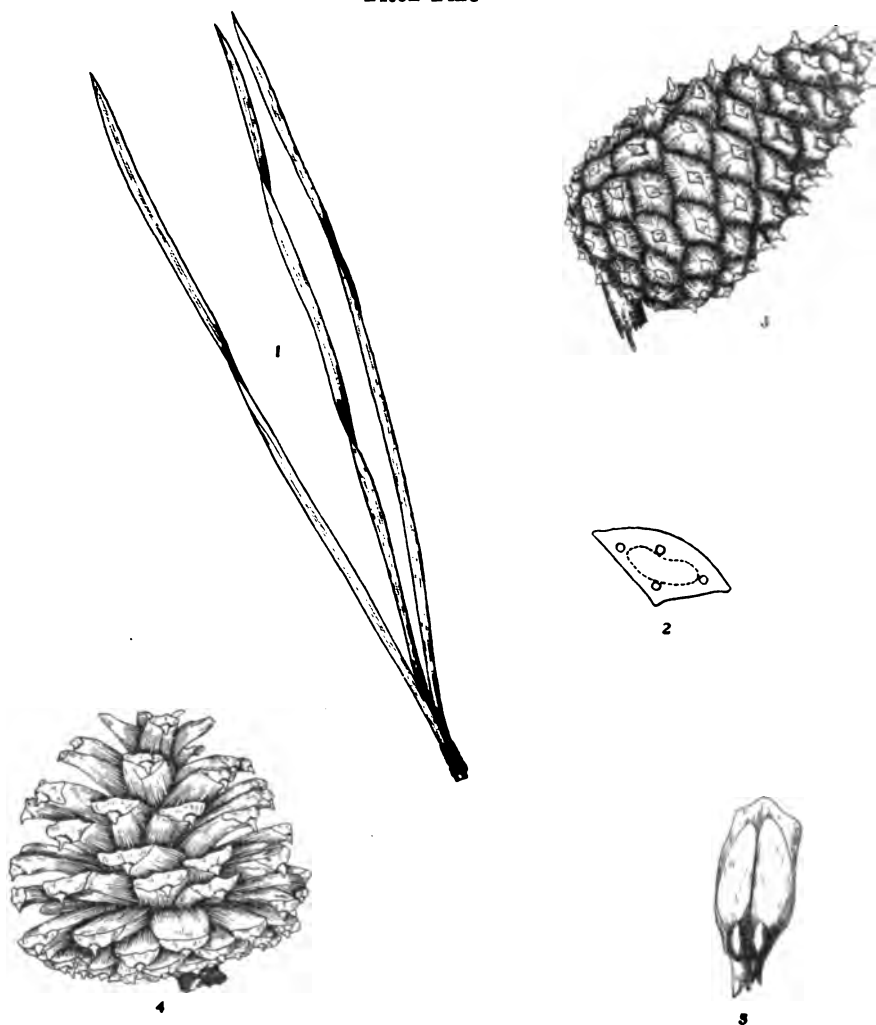
BARK.—Twigs at first rusty-tomentose, later smooth and light brown, finally thin, smooth, greenish; thick, dark gray on the trunk, shallowly fissured into broad, scaly ridges. Plate I.

WOOD.—Light, soft, weak, compact, straight-grained, easily worked, light brown, with thin, whitish sapwood. Page 215.

DISTRIBUTION.—Common throughout the state up to 1,000 feet altitude, but most abundant in the Champlain and Connecticut valleys.

HABITAT.—Prefers a light, fertile loam; sandy soils of granite origin.

NOTES.—The white pine, growing as it does sometimes to immense height, was one of the loftiest trees of the primeval New England forest. Lumbermen have removed most of the patriarchs and only the younger trees commonly remain. Its slender lustrous leaves are borne in close clusters and give it a beauty and delicacy of foliage possessed by no other pine. It is one of the most valuable and most rapidly growing of Vermont's timber trees and is being planted every year by the thousands in our state forests and by private owners.

Pitch Pine

1. Cluster of leaves, x 1.
2. Cross-section of leaf, enlarged.
3. Unopened cone, x 1.
4. Opened cone, x 1.
5. Cone-scale with seeds, x 1.

PINACEAE**Pitch Pine*****Pinus rigida* Mill.**

HABIT.—A small tree 40-60 feet high, with a short, crooked trunk 1-2 feet in diameter; coarse, gnarled branches form an irregular, open, pyramidal or rounded crown; a decidedly scraggly tree.

LEAVES.—In clusters of three; 2-5 inches long; stout, stiff, tapering to a thick tip; more or less twisted, divergent from a short sheath; bright yellow-green. Persistent 2-3 years.

FLOWERS.—May-June; monoecious; the staminate in short, crowded, cylindrical spikes about $\frac{3}{4}$ inch long, yellowish; the pistillate lateral, subglobose, short-stalked, more or less clustered, reddish-green, about $\frac{1}{8}$ inch long.

FRUIT.—Autumn of second season, opening soon after, but persistent on the tree for 10-12 years; lateral, at about a right angle to the branch, either solitary or in whorls of several; ovoid to nearly globose, nearly sessile cones 1-3 inches long; scales thickened at the apex and armed with a stiff, recurved prickle; seeds triangular, dark brown, $\frac{1}{4}$ inch long, with wings about $\frac{1}{2}$ inch long.

WINTER-BUDS.—Cylindrical to ovoid, sharp-pointed, dark red-brown, about $\frac{1}{2}$ inch long.

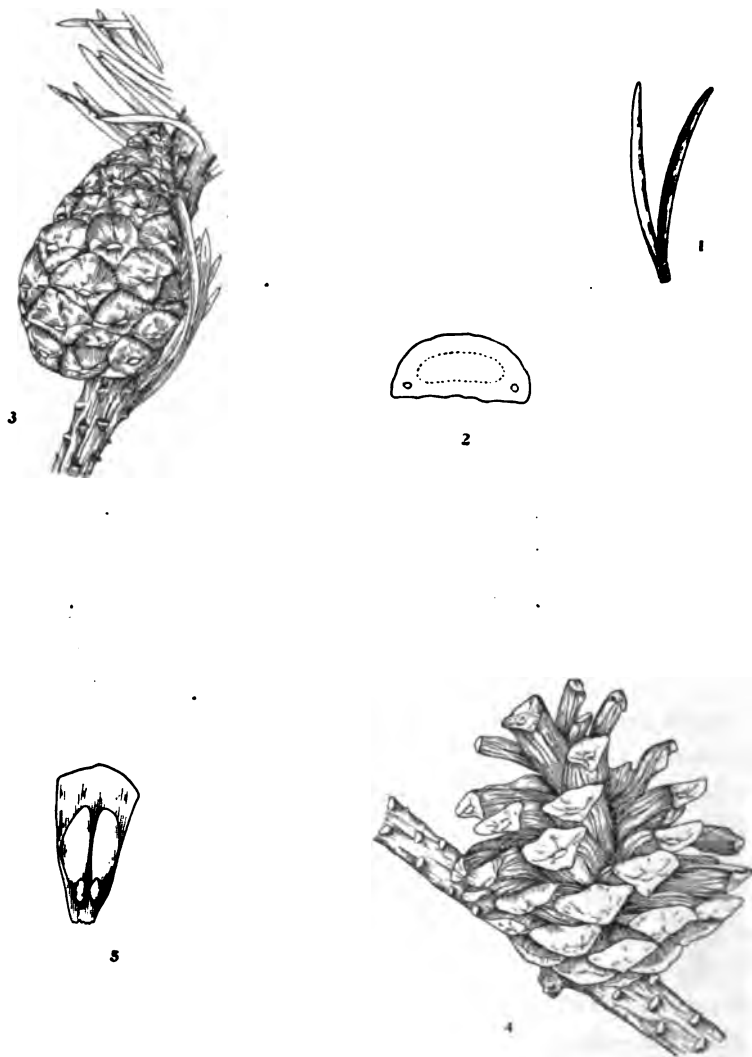
BARK.—Twigs smooth, light green, becoming yellow, finally dark gray-brown and rough with the persistent bases of fallen leaves; thin, red-brown on the trunk, with broad, flat ridges and deepish furrows. Plate I.

WOOD.—Light, soft, weak, brittle, coarse-grained, very durable, light brown or red, with thick, yellowish to whitish sapwood.

DISTRIBUTION.—Common in the northern portion of the Champlain Valley, especially along the lower courses of the Winooski, La-moille and Missisquoi Rivers; less common in the Connecticut Valley as far north as Wells River.

HABITAT.—Barren, sandy soil.

NOTES.—This tree is a prolific seeder. It is able to sprout from the stump and is fire-resistant. In suitable places it forms dense groves of small trees, forty to sixty feet in height. The individual trees sometimes are picturesque but neither graceful nor very attractive in appearance. The branches even of the smaller trees mature numerous cones, which are long persistent. They are about two inches long, and, as has been said, they have scales tipped with sharp recurved prickles, a character which may aid in its recognition.

Gray Pine. Jack Pine

(Mich. Trees).

1. Cluster of leaves, x 1.
2. Cross-section of leaf, enlarged.
3. Branchlet with unopened cone, x 1.
4. Branchlet with opened cone, x 1.
5. Cone-scale with seeds, x 1.

PINACEAE**Gray Pine. Jack Pine**

Pinus banksiana Lamb. [*Pinus divaricata* (Ait.) DuMont de Cours.]

HABIT.—Usually a small tree 15-30 feet high, with a trunk diameter of 8-12 inches; forming usually a scrubby, stunted, and variously distorted crown.

LEAVES.—In clusters of two; about 1 inch long; narrow-linear, with sharp-pointed apex; stout, curved or twisted, divergent from a short sheath; dark gray-green. Persistent 2-3 years.

FLOWERS.—May-June; monoecious; the staminate in oblong clusters $\frac{1}{2}$ inch long, composed of many sessile, yellow anthers imbricated upon a central axis; the pistillate in subglobose clusters, composed of many carpel-like, purple scales (subtended by small bracts) spirally arranged upon a central axis.

FRUIT.—Autumn of second or third season, but remaining closed for several years and persistent on the tree for 10-15 years; erect, usually incurved, oblong-conical, sessile cones, $1\frac{1}{2}$ -2 inches long; scales thickened at the apex; seeds triangular, nearly black, $\frac{3}{8}$ inch long, with wings $\frac{1}{2}$ inch long.

WINTER-BUDS.—Terminal bud $\frac{1}{4}$ inch long, ovoid, rounded, pale brown; lateral buds smaller.

BARK.—Twigs yellow-green, becoming purple, finally dark red-brown and rough with the persistent bases of fallen leaves; thin, dark red-brown on the trunk, with shallow, rounded ridges, rough-scaly on the surface.

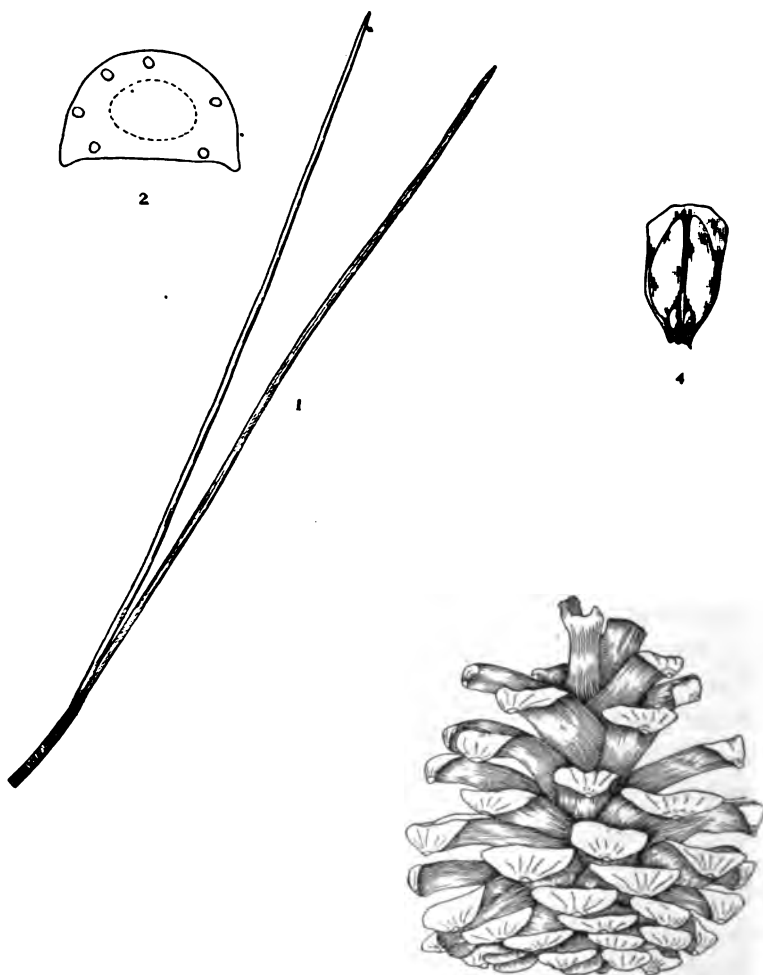
WOOD.—Light, soft, weak, close-grained, light brown, with thick, whitish sapwood.

DISTRIBUTION.—Reported at Monkton and Starksboro in Addison county and at Fairfax in Franklin county; but few trees at each station.

HABITAT.—Sandy, sterile soil; rocky slopes.

NOTES.—The gray pine is the smallest of the Vermont pines, with sprawling habit and short stout leaves, giving the tree a bristly, stunted appearance. Its characteristic cones are pointed and curved toward the main axis of the stem, often partially encircling it. The gray pine is a northern species extending to the Arctic region, and the line of its southeastern limit passes through northern Vermont. It is one of the rarest of our trees, and but few specimens are known to occur within our State borders. The remaining trees should be sought out and spared because of their scientific interest.

Red Pine. Norway Pine



(Mich. Trees).

1. Cluster of leaves, x 1.
2. Cross-section of leaf, enlarged.
3. Opened cone, x 1.
4. Cone-scale with seeds, x 1.

PINACEAE**Red Pine. Norway Pine*****Pinus resinosa* Ait.**

HABIT.—A large tree 50-75 feet high, with a trunk diameter of 2-3 feet; stout, horizontal branches form a broad, rounded, rather open crown.

LEAVES.—In clusters of two; 4-6 inches long; slender, straight, needle-shaped, sharp-pointed, flexible, from elongated, persistent sheaths; lustrous dark green. Persistent 4-5 years.

FLOWERS.—April-May; monoecious; the staminate in oblong, dense clusters, $\frac{1}{2}$ - $\frac{3}{4}$ inch long, composed of many sessile, purple anthers imbricated upon a central axis; the pistillate single or few-clustered at the end of the branchlets, subglobose; scales ovate, scarlet, borne on stout peduncles covered with pale brown bracts.

FRUIT.—Autumn of second season, falling the next summer; ovate-conical, nearly sessile cones, about 2 inches long; scales thickened at the apex; seeds oval, compressed, light mottled-brown, with wings $\frac{1}{2}$ - $\frac{3}{4}$ inch long.

WINTER-BUDS.—About $\frac{3}{4}$ inch long, ovoid or conical, acute, red-brown, with rather loose scales.

BARK.—Twigs orange-brown, becoming rough with the persistent bases of leaf-buds; thick and red-brown on the trunk, shallowly fissured into broad, flat ridges. Plate I.

WOOD.—Light, hard, very close-grained, pale red, with thin, yellow to white sapwood. Page 217.

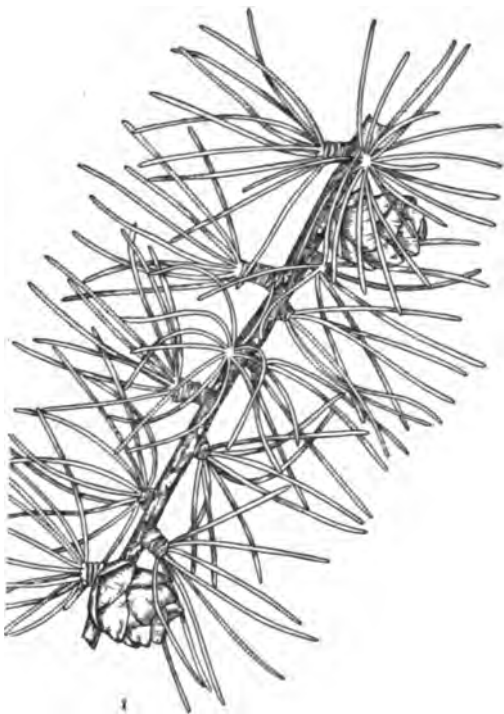
DISTRIBUTION.—Scattered groups or small groves occur on the dry, rocky headlands of Lake Champlain and it may be found in similar soils in the river valleys throughout Vermont, although it is less frequent in the southern counties.

HABITAT.—Poor soils; sandy plains and dry woods.

NOTES.—The red pine makes a rapid growth on our better soils. It is difficult to transplant but should be used extensively.

The name "red pine" is appropriate both because of the pale red color of the heart wood and the distinctly reddish cast of the bark. This species does not grow in Norway or elsewhere in Europe, and it is said that it received the name from the town of Norway, Maine. The name "Norway pine" has so little fitness as applied to this tree, and evidently is so misleading that its use is to be discouraged.

The picturesqueness and individuality of the red pine commend it for wider use as an ornamental tree.

Tamarack

4



3



2

(Mich. Trees).

1. Autumn branchlet, with leaves and cones, x 1.
2. Cross-section of leaf, enlarged.
3. Fruiting branchlet in winter, x 1.
2. Cone-scale with seeds, x 2.

PINACEAE

Tamarack

Larix laricina (DuRoi) Koch [*Larix americana* Michx.]

HABIT.—A tree sometimes 80-100 feet high, with a trunk diameter of 1-2 feet; forming a broad, open, irregular crown of horizontal branches.

LEAVES.—Scattered singly along the leading shoots or clustered on the short lateral branchlets; linear, with blunt apex; rounded above, keeled beneath; about 1 inch long; bright green; sessile. Deciduous in early autumn.

FLOWERS.—May, with the leaves; monoecious; the staminate sessile, subglobose, yellow, composed of many short-stalked anthers spirally arranged about a central axis; the pistillate oblong, short-stalked, composed of orbicular, green scales (subtended by red bracts) spirally arranged about a central axis.

FRUIT.—Autumn of first season, but persistent on the tree for a year longer; ovoid, obtuse, light brown, short-stalked cones, $\frac{1}{2}$ - $\frac{3}{4}$ inch long; seeds $\frac{1}{8}$ inch long, with pale brown wings widest near the middle.

WINTER-BUDS.—Small, globose, lustrous, dark red.

BARK.—Twigs at first grayish, glaucous, later light orange-brown, and finally dark brown; red-brown and scaly on the trunk. Plate I.

WOOD.—Heavy, hard, very strong, coarse-grained, very durable, light brown, with thin, nearly white sapwood. Page 219.

DISTRIBUTION.—Common throughout Vermont, except in the lower Connecticut valley.

HABITAT.—Cold, deep swamps.

NOTES.—The tamarack becomes a picturesque tree in old age. It grows slowly in swamps, but rapidly on well-drained soils. It is our only cone-bearing tree which drops its leaves in the autumn. The tamarack is an attractive, conical tree, its graceful form and full clusters of slender, delicate leaves giving it a well-marked individuality. Its deep red, fleshy cones, which open in June, resemble flower clusters.

THE SPRUCES

Every Vermonter should know and appreciate the spruces for the mountain spruce and the sugar maple are our most characteristic trees. The forests of North America contain seven species of spruce, three of which occur in Vermont.¹

The spruces are northern trees, and Vermont lies rather south of the belt of their most abundant growth in northeastern America. It is therefore our mountain sides and cool swamps which furnish conditions suitable for their best development.

The flowering cones are similar to those of the pine in general characters. The flowers appear in spring and the cones mature the following autumn, the seeds being shed during autumn or early winter.

Until recently botanists considered the two species here described as the red spruce and the black spruce to be simply varieties of one species, to which was given the common name of black spruce. In the lumber trade all three kinds are handled, without discrimination, as "spruce." As a matter of fact, the red spruce furnishes nearly all of the spruce lumber cut in Vermont. Spruce gum also comes chiefly from the red spruce, although it is formed by the other species.

¹ *Introduced species.*—The Norway spruce (*Picea abies*) is commonly cultivated in Vermont dooryards, parks and cemeteries, and is superior to our native trees for such purposes. It is recognized easily by its more pendulous branches and very large slender cones, five to seven inches long.

The Colorado blue spruce (*P. pungens*) is occasionally planted. This is characterized by its beautiful glaucous-blue foliage. The cones are three to five inches long.

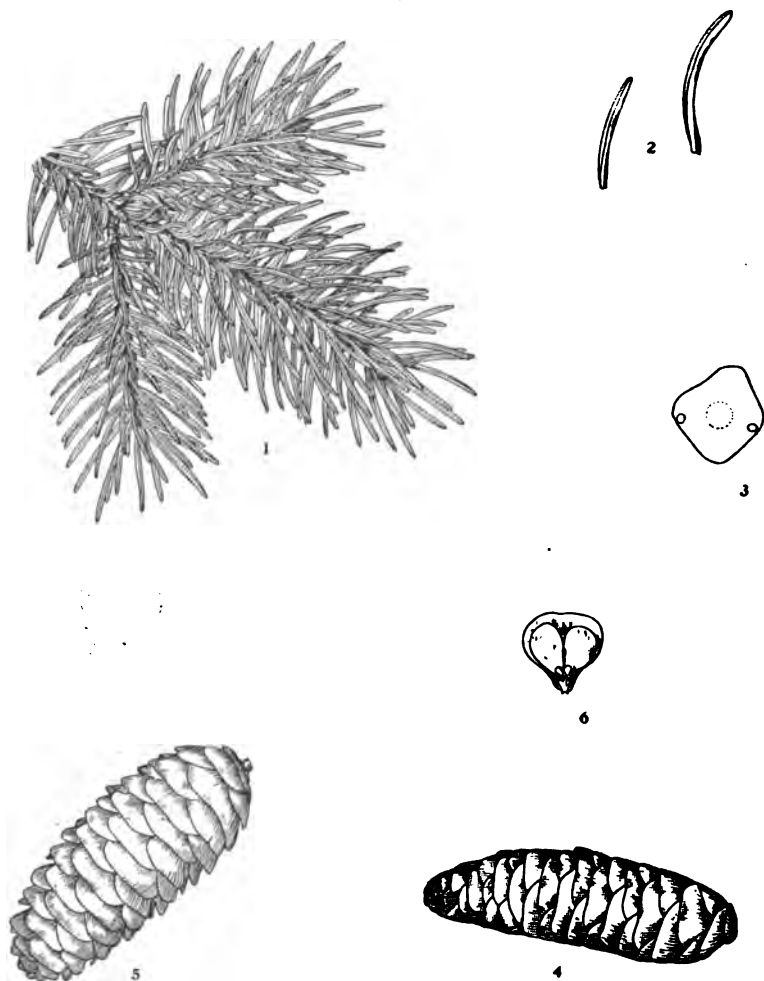
SUMMER AND WINTER KEY TO THE SPECIES OF PICEA

- a.* Leaves $\frac{1}{8}$ - $\frac{5}{8}$ inch long; twigs conspicuously pubescent.
 - b.* Leaves usually $\frac{1}{8}$ - $\frac{3}{8}$ inch long, typically blunt-pointed, dark blue-green; cones about 1 inch long, persistent on the branches for many years, their scales ragged-toothed; tree typical of swamps **P. mariana**, p. 43.
 - bb.* Leaves $\frac{3}{8}$ - $\frac{5}{8}$ inch long, typically sharp-pointed, dark yellow-green; cones $1\frac{1}{4}$ -2 inches long, falling mostly during their first winter, their scales not ragged-toothed; tree typical of well-drained uplands and rocky slopes..... **P. rubra**, p. 41.
- aa.* Leaves $\frac{5}{8}$ -1 inch long; twigs not conspicuously pubescent, usually glabrous.
 - b.* Cones 1-2 inches long, maturing and falling in first season, their scales not toothed; leaves ill-scented when bruised,

P. canadensis, p. 39.
 - bb.* Cones 3-6 inches long, maturing and falling in second season, their scales finely toothed; leaves not ill-scented when bruised,

P. abies, p. 45.

White Spruce



(Mich. Trees).

1. Winter branchlet, x 1.
2. Leaves, x 1.
3. Cross-section of leaf, enlarged.
4. Unopened cone, x 1.
5. Partly opened cone, x 1.
6. Cone-scale with seeds, x 1.

PINACEAE**White Spruce**

Picea canadensis (Mill.) BSP. [*Picea alba* Link]

HABIT.—A tree 70-100 feet high, with a trunk diameter of 1-3 feet; forming a rather broad, open, pyramidal crown.

LEAVES.—Spirally arranged, but crowded on the upper side of the branches by the twisting of those on the under side; awl-shaped, 4-sided, incurved; dark blue-green; about $\frac{3}{4}$ inch long; ill-scented when bruised. Persistent for several years.

FLOWERS.—May; monoecious; the staminate in oblong-cylindrical, long-stalked clusters, $\frac{1}{2}$ - $\frac{3}{4}$ inch long, composed of many spirally arranged, red anthers; the pistillate in oblong-cylindrical clusters, composed of broad, reddish scales (subtended by orbicular bracts) spirally arranged upon a central axis.

FRUIT.—Autumn or early winter of first season, falling soon after discharging the seeds; pendent, slender, oblong-cylindrical, nearly sessile cones, 1-2 inches long; seeds about $\frac{1}{8}$ inch long, with large wings oblique at the apex.

WINTER-BUDS.—Broadly ovoid, obtuse, light brown, $\frac{1}{8}$ - $\frac{1}{4}$ inch long.

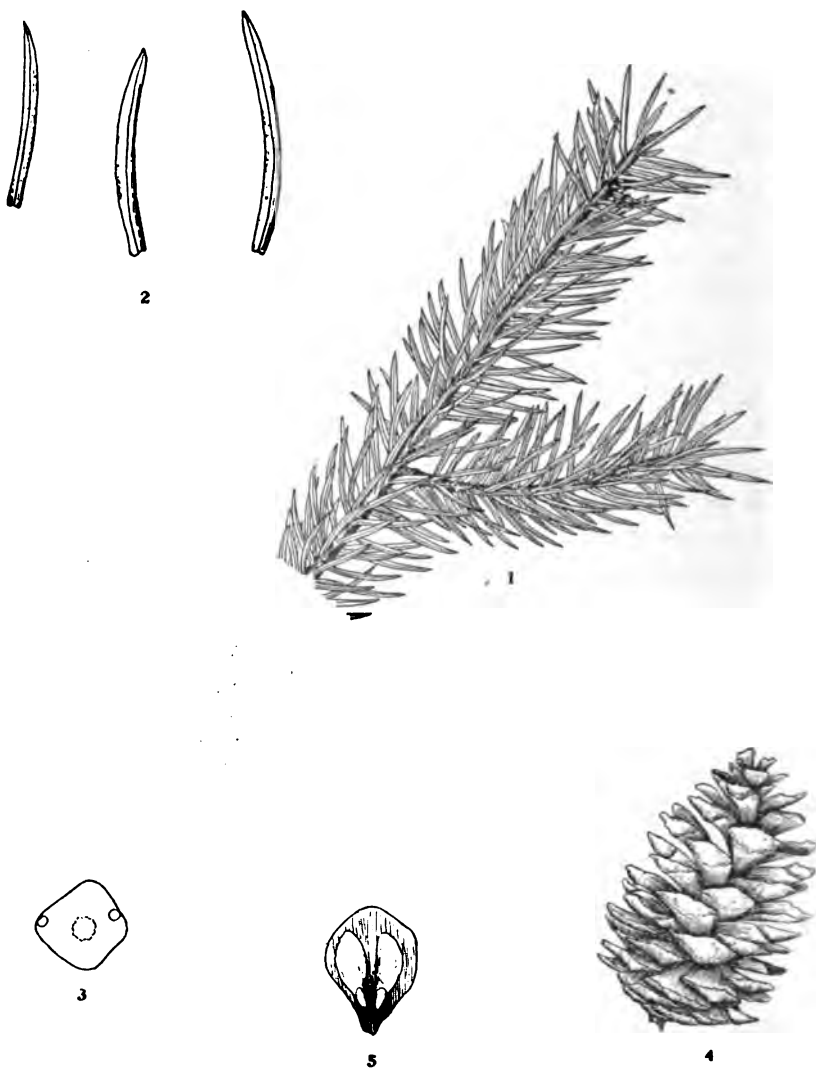
BARK.—Twigs smooth, gray-green, becoming orange-brown, finally dark gray-brown; thin, light gray-brown on the trunk, separating into thin, plate-like scales.

WOOD.—Light, soft, weak, straight-grained, light yellow, with sapwood of the same color.

DISTRIBUTION.—Common in the northeastern quarter of Vermont; also on some of the islands of Lake Champlain; has been reported from other isolated districts.

HABITAT.—Low, damp woods; banks of streams; borders of lakes; high, rocky or sandy slopes.

NOTES.—This is a northern tree which extends from Canada into northern Vermont. It occurs along the Connecticut river to the Fifteen Mile Falls (South Lunenburg), and on the eastern arm of the Y of the Green Mountains to the Montpelier and Wells River railroad, or perhaps a little farther south. It is common on some of the islands of Lake Champlain and is scattered through the forests of Essex county. The strong polecat odor of the young branches is characteristic and will aid in its recognition. Because of this odor it is sometimes called "skunk spruce." Lumbermen do not separate this from the other spruces and the tree is nearly equal in size to the red spruce.

Red Spruce

1. Winter branchlet, x 1.
2. Leaves, x 2.
3. Cross-section of leaf, enlarged.
4. Opened cone, x 1.
5. Cone-scale with seeds, x 1.

PINACEAE**Red Spruce**

Picea rubra (DuRoi) Dietr. [*Picea rubens* Sarg.]

HABIT.—A tree 50-80 feet high, with a trunk diameter of 1-3 feet; forming a narrow, conical crown of slender, spreading branches reaching nearly to the ground; when crowded, usually lacking branches for much of its length.

LEAVES.—Spirally arranged, pointing outward in all directions; awl-shaped, 4-sided, mostly sharp or thickly taper-pointed, more or less incurved; slender; lustrous, dark yellow-green; $\frac{3}{8}$ - $\frac{5}{8}$ inch long. Persistent for several years.

FLOWERS.—May; monoecious; the staminate in ovoid clusters, about $\frac{1}{2}$ inch long, composed of many spirally arranged, bright red anthers; the pistillate in oblong-cylindrical clusters, $\frac{3}{4}$ inch long, composed of thin, rounded, purple scales (subtended by small, obovate bracts) spirally arranged upon a central axis.

FRUIT.—Autumn of first season, falling mostly during their first winter; pendent, elongate-ovoid, short-stalked cones, $1\frac{1}{4}$ -2 inches long; seeds about $\frac{1}{8}$ inch long, dark brown, with short, broad wings.

WINTER-BUDS.—Ovoid, acute, light red-brown, puberulous, about $\frac{3}{16}$ inch long.

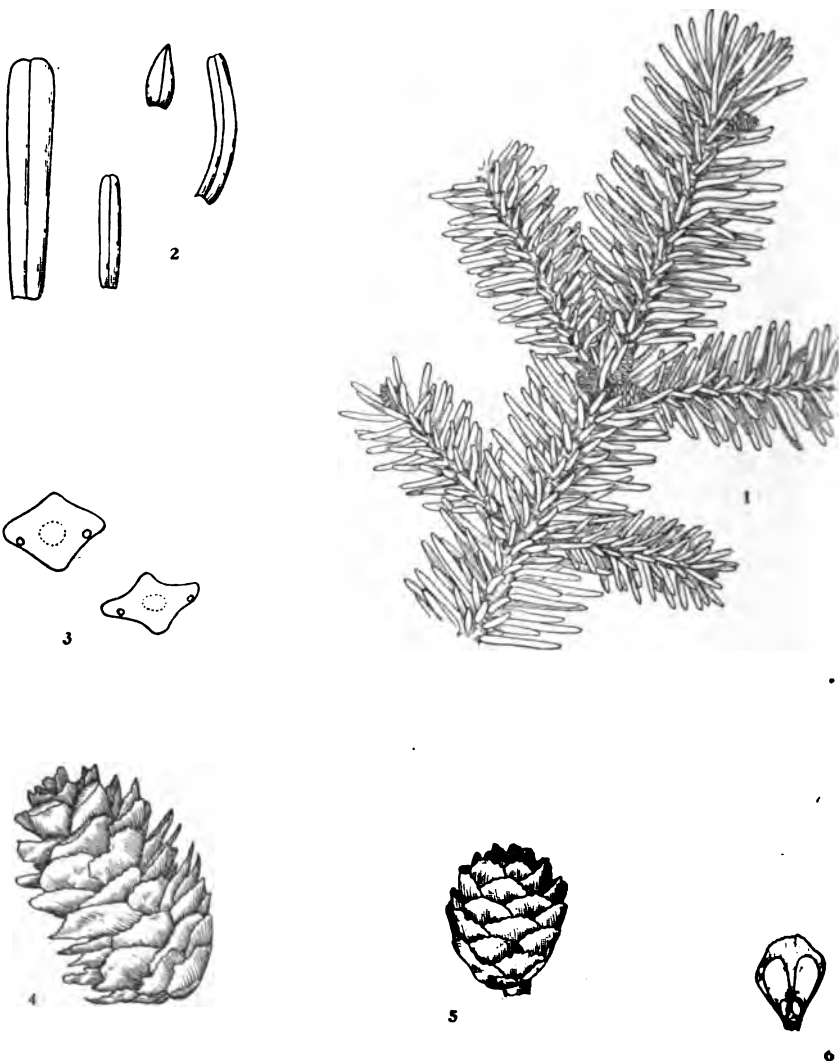
BARK.—Twigs at first greenish, with dense, whitish pubescence, becoming light brown and rusty-pubescent; thin, red-brown on the trunk, flaky with thin scales.

WOOD.—Light, soft, weak, close-grained, pale and tinged with red, with thin, paler sapwood. Page 217.

DISTRIBUTION.—Common throughout Vermont especially on the mountain slopes.

HABITAT.—Well-drained uplands; rocky slopes with thin soil; sometimes extending down to the borders of swamps.

NOTES.—This is the common spruce of our mountain forests, the vast green expanse of which suggested the names of both mountain range and State. It is not distinguished commonly from the preceding species and both are known as "black spruce." It attains a height of from seventy to one hundred feet and large logs may be three or more feet in diameter. When growing in open fields it often forms a conical head with the branches, especially of the younger trees, brushing the ground. It frequently is planted as an ornamental tree in Vermont, but its slower growth and less symmetrical form make it less desirable for this purpose than the native white spruce or Norway spruce.

Swamp Spruce. Black Spruce

(Mich. Trees).

1. Winter branchlet, x 1.
2. Leaves, x 2.
3. Cross-sections of leaves, enlarged.
- 4-5. Opened cones, x 1.
6. Cone-scale with seeds, x 1.

PINACEAE

Swamp Spruce. Black Spruce

Picea mariana (Mill.) BSP. [*Picea nigra* Link]

HABIT.—A small tree 20-50 feet high, with a trunk diameter of 6-12 inches; forming a narrow-based, conical, more or less irregular crown of short, slender, horizontal branches; often small and stunted.

LEAVES.—Spirally arranged, spreading in all directions; awl-shaped, 4-sided, blunt at the apex, more or less incurved; stiff; dark blue-green and glaucous; $\frac{1}{8}$ - $\frac{3}{8}$ inch long. Persistent for several years.

FLOWERS.—May; monoecious; the staminate in subglobose clusters, about $\frac{1}{2}$ inch long, composed of many spirally arranged, dark red anthers; the pistillate in oblong-cylindrical clusters, composed of broad, purple scales (subtended by rounded, toothed, purple bracts) spirally arranged upon a central axis, about $\frac{1}{2}$ inch long.

FRUIT.—Autumn of first season, but persistent on the branch for many years; pendent, ovoid, short-stalked cones, about 1 inch long; seeds about $\frac{1}{8}$ inch long, with pale brown wings $\frac{1}{2}$ inch long.

WINTER-BUDS.—Ovoid, acute, light red-brown, puberulous, $\frac{1}{8}$ inch long.

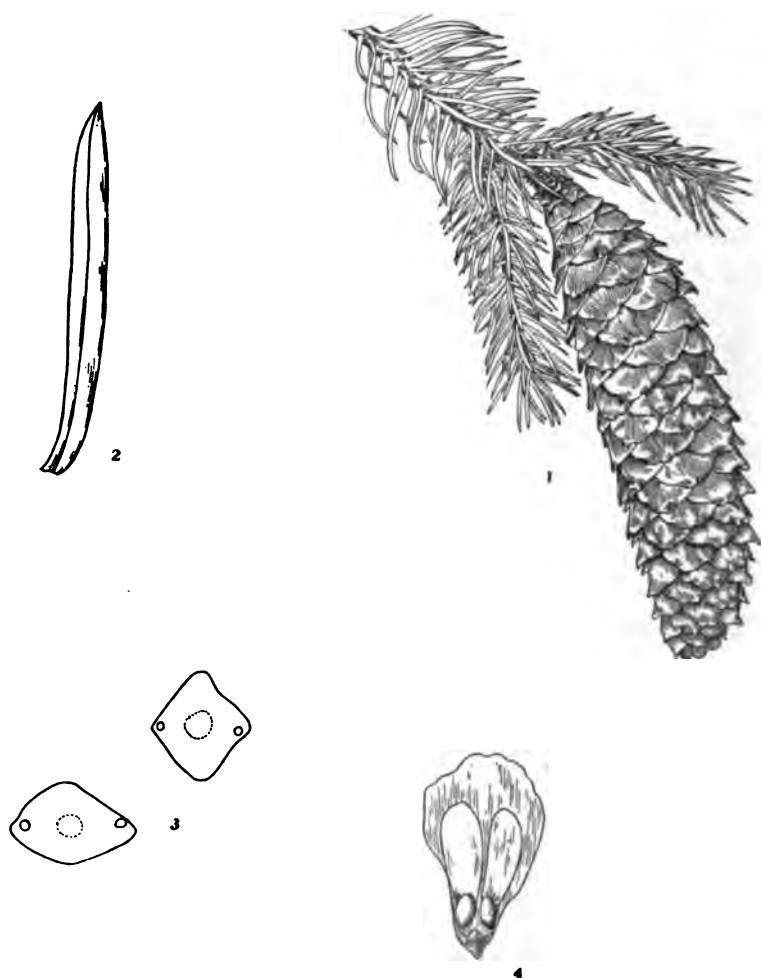
BARK.—Twigs at first green and rusty-pubescent, becoming dull red-brown and rusty-pubescent; thin, gray-brown on the trunk, separating into thin, appressed scales.

WOOD.—Light, soft, weak, pale yellow-white, with thin, pure white sapwood.

DISTRIBUTION.—This is the common spruce of the sphagnum (peat moss) swamps of the Champlain valley. It is also common in Essex and Franklin counties and probably occurs similarly in the other parts of Vermont, especially in peat bogs, but the distribution is not well known because of its confusion until recently with the red spruce.

HABITAT.—Cold, sphagnum bogs and swamps; shores of lakes.

NOTES.—The black spruce is short-lived. It is undesirable for ornamental planting, as the lower branches die early, making an unattractive evergreen. A small, semi-prostrate, sterile form, *Picea mariana*, *forma semiprostrata*, occurs on the summit of Mt. Mansfield.

Norway Spruce

(Mich. Trees).

1. Branchlet with partly opened cone, $\times \frac{1}{2}$.
2. Leaf, $\times 3$.
3. Cross-sections of leaves, enlarged.
4. Cone-scale with seeds, $\times 1$.

PINACEAE

Norway Spruce

Picea abies (L.) Karst. [*Picea excelsa* Link]

HABIT.—A tree 50-70 feet high, with a trunk diameter of 1-3 feet; forming a dense, conical, spire-topped crown of numerous, drooping branches which persist nearly to the ground.

LEAVES.—Spirally arranged along the twig; crowded; $\frac{3}{4}$ -1 inch long; rigid, curved, acute; lustrous, dark green. Persistent 5-7 years.

FLOWERS.—May; monoecious; the staminate in ovoid to subglobose clusters, long-stalked, reddish to yellowish, $\frac{3}{4}$ -1 inch long; the pistillate in cylindrical clusters, sessile, erect, $1\frac{1}{2}$ -2 inches long.

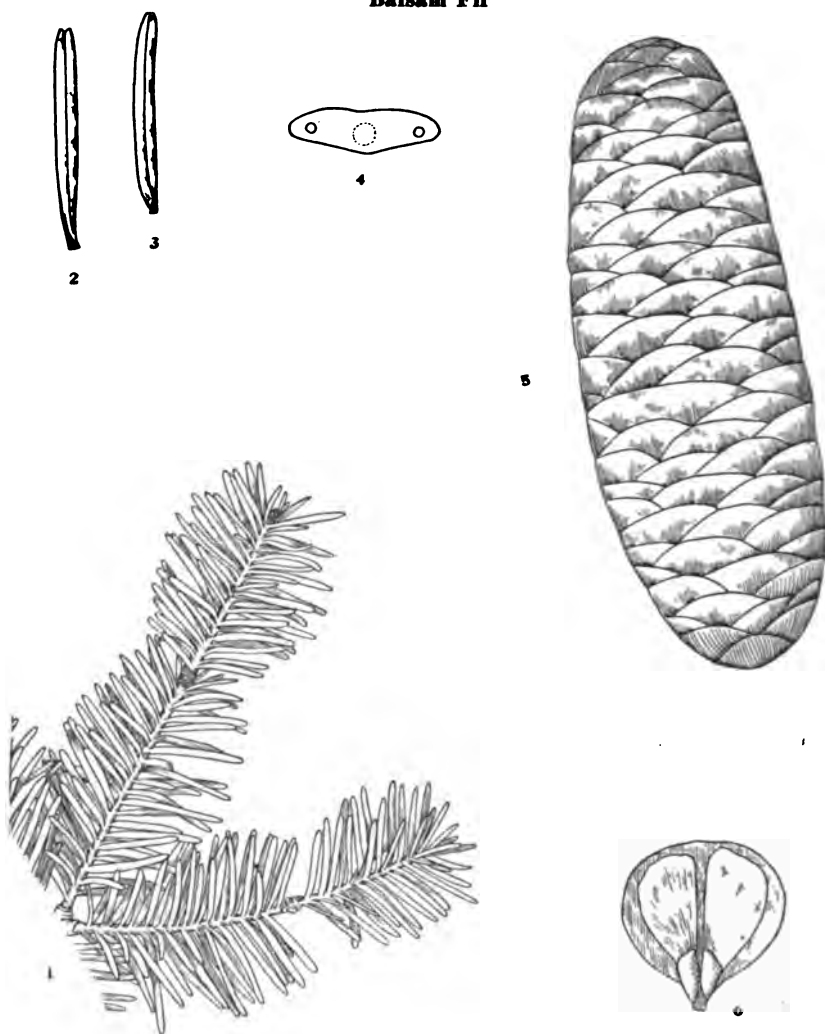
FRUIT.—Autumn of second season; sessile, cylindrical cones 3-6 inches long, pendent from the tips of the uppermost branches; sterile scales very short, toothed; seeds red-brown, rough, $\frac{1}{8}$ inch long, with long wings.

WINTER-BUDS.—Ovoid, acute, red-brown, not resinous, about $\frac{3}{8}$ inch long.

BARK.—Twigs red- or orange-brown, smooth or corrugated; becoming thin and gray-brown on old trunks, slightly fissured, scaly.

WOOD.—Light, strong, tough, elastic, soft, fined-grained, white, with thick, indistinguishable sapwood.

NOTES.—This tree is native throughout northern Europe and Asia where it grows to a height of 120 to 150 feet. It is perfectly hardy here and is the common spruce found in dooryards throughout Vermont. As it adapts itself to a variety of soils and climates and grows rapidly, it is especially desirable for ornamental planting, hedges and windbreaks. One of the best known plantations of this spruce is a small area on the Billings estate at Woodstock, which was planted nearly 40 years ago.

Balsam Fir

(Mich. Trees).

1. Winter branchlet, x 1.
- 2-3. Leaves, x 2.
4. Cross-section of leaf, enlarged.
5. Unopened cone, x 1.
6. Cone-scale with seeds, x 1.

PINACEAE**Balsam Fir*****Abies balsamea* (L.) Mill.**

HABIT.—A slender tree 40-60 feet high, with a trunk diameter of 12-18 inches; branches in whorls of 4-6, forming a symmetrical, open crown widest at the base and tapering regularly upward.

LEAVES.—Scattered, spirally arranged in rows, on young trees at right angles to the branch, on old trees covering the upper side of the branch; narrowly linear, with apex acute or rounded; $\frac{1}{2}$ - $1\frac{1}{4}$ inches long; lustrous, dark green above, pale beneath; sessile; aromatic. Persistent 8-10 years.

FLOWERS.—May; monoecious; the staminate oblong-cylindrical, yellow, $\frac{1}{4}$ inch long, composed of yellow anthers (subtended by scales) spirally arranged upon a central axis; the pistillate oblong-cylindrical, 1 inch long, composed of orbicular, purple scales (subtended by yellow-green bracts) spirally arranged upon a central axis.

FRUIT.—Autumn of first season; oblong-cylindrical, erect, puberulous, dark purple cones, 2-4 inches long, about 1 inch thick; seeds $\frac{1}{4}$ inch long, shorter than their light brown wings.

WINTER-BUDS.—Globose, orange-green, resinous, $\frac{1}{8}$ - $\frac{1}{4}$ inch in diameter.

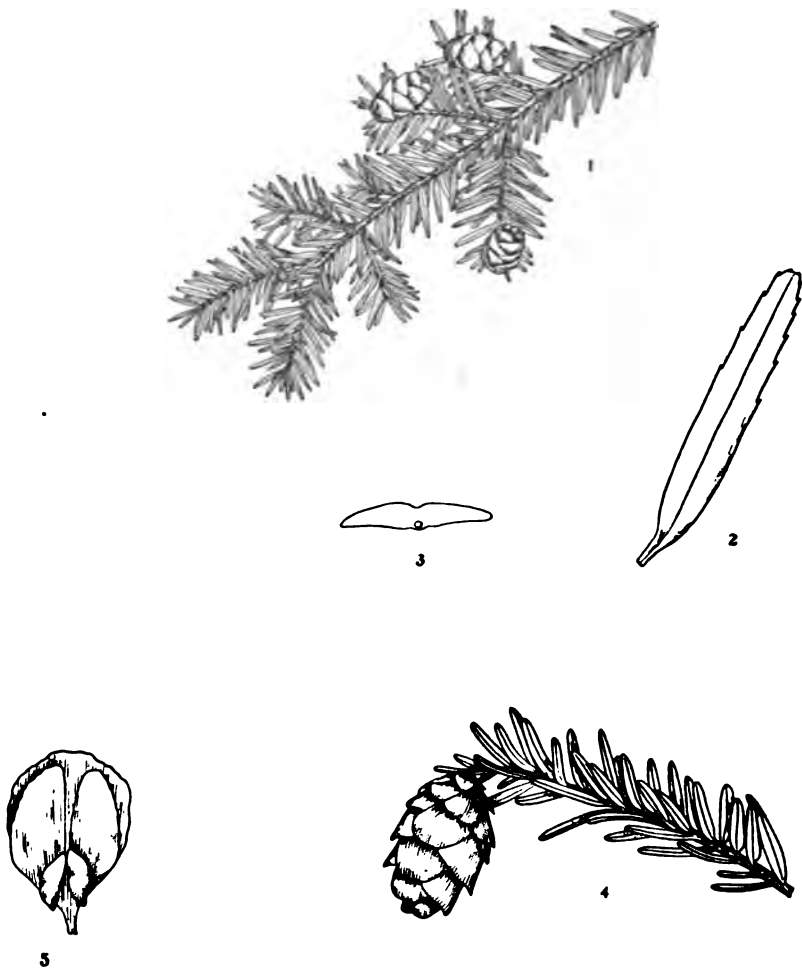
BARK.—Twigs at first grayish and pubescent, becoming gray-brown and smooth; thin and smooth on young trunks, pale gray-brown and marked by swollen resin chambers; red-brown on old trunks and somewhat roughened by small, scaly plates.

WOOD.—Very light, soft, weak, coarse-grained, perishable, pale brown, with thick, lighter colored sapwood. Page 221.

DISTRIBUTION.—Common in the mountain forests throughout Vermont, ascending to the summits of Mt. Mansfield and Camel's Hump, although there it is reduced to a low, scrubby growth; not reported in the Connecticut valley south of Hartland.

HABITAT.—Cold, wet woods and swamps, in the higher altitudes.

NOTES.—The balsam fir, more familiarly known as the fir tree or balsam, is a slender, graceful tree when growing in open ground. It bears a general resemblance to the spruces, but is distinguished easily from them on close observation. The leaves are flat, gray on the under side, with a conspicuous green midrib. The erect cones, 2 to 4 inches long, stand like Christmas candles on the upper branches. There is a characteristic fragrance from the bruised leaves and they are much prized for making pillows.

Hemlock

(Mich. Trees).

1. Fruiting branch viewed from beneath, x $\frac{1}{4}$.
2. Leaf, x 3.
3. Cross-section of leaf, enlarged.
4. Branchlet with partly opened cone, x 1.
5. Cone-scale with seeds, x 3.

PINACEAE

Hemlock

Tsuga canadensis (L.) Carr.

HABIT.—A large tree 60-80 feet high, with a trunk 2-4 feet in diameter; forming a rather broad, open, somewhat irregular-pyramidal crown of slender, horizontal branches.

LEAVES.—Spirally arranged around the branch, but appearing 2-ranked by the twisting of their petioles; linear, flat, rounded at the apex; about $\frac{1}{2}$ inch long; dark yellow-green and shining above, hoary beneath; short-petioled. Persistent about 3 years.

FLOWERS.—May; monoecious; the staminate axillary, short-stalked, light yellow, about $\frac{3}{8}$ inch long, composed of subglobose clusters of stamens; the pistillate terminal, oblong, pale green, $\frac{1}{8}$ inch long, the scales short, pinkish.

FRUIT.—Autumn of first season, gradually losing their seeds during the winter and falling the next spring; oblong-ovoid, acute, short-stalked, red-brown cones, about $\frac{3}{4}$ inch long; seeds $\frac{1}{8}$ inch long, with wings about twice as long.

WINTER-BUDS.—Ovoid, obtuse, red-brown, slightly puberulous, $\frac{1}{16}$ inch long.

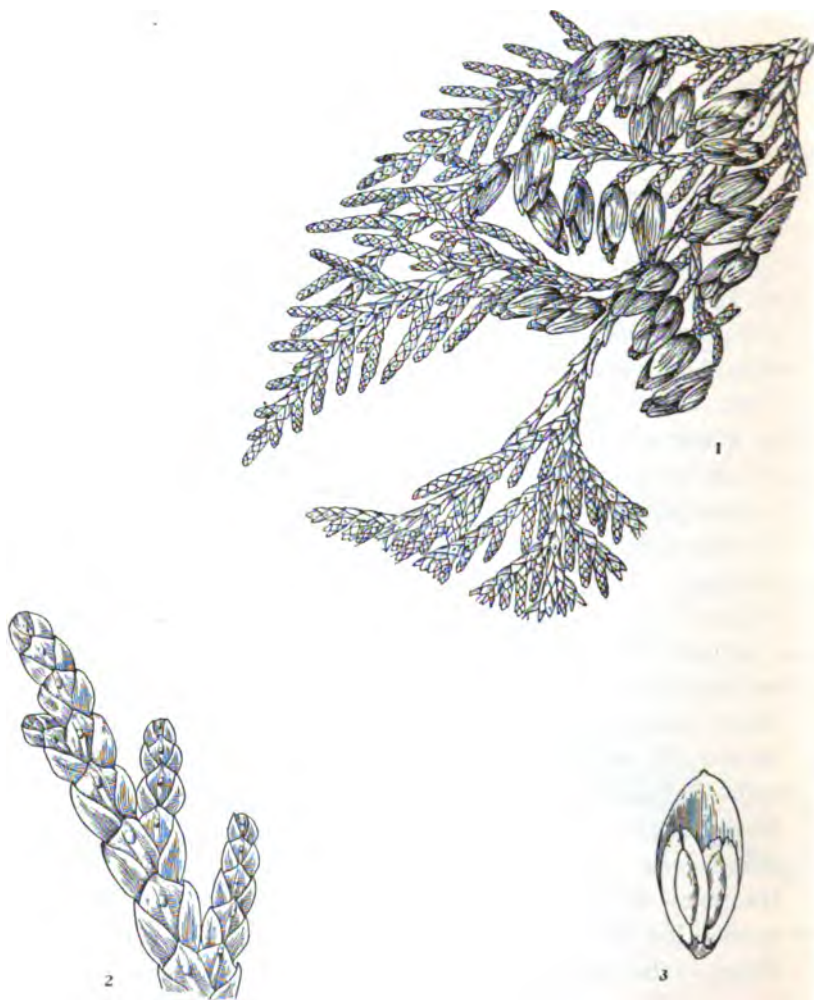
BARK.—Twigs at first pale brown and pubescent, becoming glabrous, gray-brown; thick, red-brown or gray on the trunk, deeply divided into narrow, rounded, scaly ridges. Plate II.

WOOD.—Light, soft, weak, brittle, coarse, and crooked-grained, not durable, ill-smelling, light red-brown, with thin, darker colored sapwood. Page 219.

DISTRIBUTION.—Common throughout Vermont, especially in the mountain forests.

HABITAT.—Rocky woods and hillsides; borders of swamps; mountain forests; low river-banks.

NOTES.—The hemlock is one of the most graceful of our ever-green trees. It may be met with almost everywhere from the low river-banks and swamps to the rocky hillsides and mountain forests. In distinguishing the hemlock from the spruce and balsam fir, one should notice the flat, petioled leaves arranged in a flattened spray with a row on the upper side lying close to the stem. The small ellipsoidal cones, scarcely more than three-fourths of an inch long, mature in the autumn and shed their seeds during the winter.

Arbor Vitae. White Cedar

(Mich. Trees).

1. Fruiting branchlet, x 1.
2. Tip of branchlet, enlarged.
3. Cone-scale with seeds, x 3.

PINACEAE**Arbor Vitae. White Cedar*****Thuja occidentalis* L.**

HABIT.—A tree 40-50 feet high, with a short, often buttressed trunk 1-2 feet in diameter, often divided into 2-3 secondary stems; forming a rather dense, wide-based, pyramidal crown.

LEAVES.—Opposite, 4-ranked, scale-like, appressed; ovate, obtuse or pointed, keeled in the side pairs, flat in the others; $\frac{1}{8}$ - $\frac{1}{4}$ inch long; yellow-green, often becoming brown in winter; strongly aromatic when crushed. Persistent 1-2 years.

FLOWERS.—April-May; usually monoecious; the staminate minute, globose, yellow, composed of 4-6 stamens arranged oppositely on a short axis; the pistillate small, oblong, reddish, composed of 8-12 scales arranged oppositely on a short axis.

FRUIT.—Early autumn of first season, but persistent on the branch through the winter; erect, short-stalked, oblong-ovoid, pale brown cones, about $\frac{1}{2}$ inch long, composed of 8-12 loose scales; seeds $\frac{1}{8}$ inch long, ovate, acute, winged.

WINTER-BUDS.—Naked, minute.

BARK.—Twigs, yellow-green, becoming light red, finally smooth, lustrous, dark orange-brown; thin, light red-brown on the trunk, slightly furrowed or deciduous in ragged strips.

WOOD.—Light, soft, brittle, rather coarse-grained, durable, fragrant, pale yellow-brown, with thin, whitish sapwood. Page 221.

DISTRIBUTION.—Common in northern and central Vermont, and as far south as Woodstock and Hartland in eastern Vermont, up to 1,000 feet altitude.

HABITAT.—Swamps and along river-banks; rocky slopes; cool, moist hillsides.

NOTES.—This tree is known popularly in Vermont as the white cedar and is recognized easily by its striking pyramidal habit of growth and, upon closer examination, by its small scale-like leaves, in four rows but so flattened on the branchlets as to form fan-like sprays.

The straight slender trunks of this species are of especial value for posts and telegraph poles. Few timbers better withstand decay in the soil, fence posts sometimes lasting thirty or forty years. It is planted commonly for hedges and other ornamental purposes.

Red Cedar

(Mich. Trees).

1. Branchlet with awl-shaped leaves, x 1.
2. Tip of branchlet, showing awl-shaped leaves, enlarged.
3. Fruiting branchlet with scale-like leaves, x 1.
4. Tip of branchlet, showing scale-like leaves, enlarged.

PINACEAE

Red Cedar

Juniperus virginiana L.

HABIT.—A medium-sized tree 30-40 feet high, with a trunk diameter of a foot; forming an irregular, pyramidal or rounded crown.

LEAVES.—Opposite, of two kinds: (1) sessile, scale-like, closely appressed, overlapping, 4-ranked, ovate, acute, $\frac{1}{16}$ inch long, (2) sessile, awl-shaped, loosely-arranged, $\frac{1}{4}$ - $\frac{1}{2}$ inch long. Persistent 5-6 years.

FLOWERS.—May; usually dioecious; minute; the staminate oblong-ovoid, composed of 4-6 shield-like scales, each bearing 4-5 yellow, globose pollen sacs; the pistillate ovoid, composed of about 3 pairs of fleshy, bluish scales, united at the base and bearing 2 ovules.

FRUIT.—Autumn of first or second season; subglobose, berry-like strobile, about $\frac{1}{4}$ inch in diameter, dark blue and glaucous; flesh sweet and resinous; seeds 2-3.

WINTER-BUDS.—Naked, minute.

BARK.—Twigs greenish to red-brown and smooth; thin, light red-brown on the trunk, exfoliating lengthwise into long, narrow, persistent strips, exposing the smooth, brown inner bark.

WOOD.—Light, soft, close-grained, brittle, weak, durable, very fragrant, dull red, with thin, whitish sapwood.

DISTRIBUTION.—Common in lower altitudes of western Vermont, less so in the mountain range of southwestern Vermont; more or less common in the Connecticut valley as far north as Fairlee.

HABITAT.—Dry, rocky hills; also borders of lakes and streams, peaty swamps.

NOTES.—Three kinds of juniper are found in Vermont, but this one, commonly known as "red cedar," is the only one which has the size and habit of a tree. It somewhat resembles the arbor vitæ, from which it may be distinguished at a distance by its less symmetrical form and darker foliage. Closer inspection shows that its scale-like leaves have little tendency to the arrangement in a plane which is characteristic of the arbor vitæ. The fruit also is distinguishable readily from that of the other cone-bearing trees. It consists of thick, fleshy scales which coalesce to form a structure looking more like a small berry than a cone, green in midsummer, becoming bluish at maturity in the autumn. The leaves of young shoots are longer than those on the older branches, with needle-like points. The heartwood of this tree is soft, red and fragrant, and that obtained from the southern states is largely used in the manufacture of pencils.

SALICACEAE—WILLOWS

The classification of the willows is a task for the specialist, even when leaves and both staminate and pistillate flowers are obtainable. For this reason the usual summer and winter keys have been omitted.

SALICACEAE

THE WILLOWS

The genus *Salix* is represented in Vermont by 25 distinct species or varieties and by a number of hybrids. The majority of these are shrubs, only a few becoming truly arborescent. Because of the similarity of their botanical characters, the frequency with which they hybridize, and the facility with which they respond to their environment, only an expert is competent to identify the species so abundant along our water courses and on the banks of our lakes and swamps. The scope of this work necessarily being limited, it has been deemed best to describe but one of our native willows and one of our foreign neighbors which is planted frequently.

Willows are introduced commonly as shade trees because they are propagated so easily by cuttings. Care should be taken, however, to select the stamen-bearing trees, both because these are more ornamental when in flower and because they do not produce the downy fruit which often is disagreeable when willows are growing near houses.

Black Willow

(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x 1.
4. Staminate flowering branchlet, x 1.
5. Staminate flower, enlarged.
6. Pistillate flowering branchlets, x 1.
7. Pistillate flower, enlarged.
8. Fruiting branchlet, x 1.

SALICACEAE**Black Willow*****Salix nigra* Marsh.**

HABIT.—A tree 30-50 feet high, with a short trunk, 1-2 feet in diameter; stout, spreading branches form a broad, rather irregular, open crown. Often a shrub.

LEAVES.—Alternate, simple, 3-6 inches long, $\frac{1}{4}$ - $\frac{3}{4}$ inch broad; lanceolate, very long-pointed, often curved at the tip; finely serrate; thin; bright green and rather lustrous above, paler and often hairy beneath; petioles very short, more or less pubescent.

FLOWERS.—May, with the leaves; dioecious; borne in crowded, slender, hairy catkins, 1-3 inches long; calyx 0; corolla 0; scales yellow, villous, with 3-6 stamens; ovary ovoid-conical, short-stalked, with stigmas nearly sessile.

FRUIT.—June; ovoid-conical capsule, $\frac{1}{8}$ inch long, containing many minute seeds which are furnished with long, silky, white hairs.

WINTER-BUDS.—Terminal bud absent; lateral buds narrow-conical, acute, lustrous, red-brown, $\frac{1}{8}$ inch long.

BARK.—Twigs glabrous or pubescent, bright red-brown, becoming darker with age; thick, dark brown or nearly black on old trunks, deeply divided into broad, flat ridges, often becoming shaggy.

WOOD.—Light, soft, weak, close-grained, light red-brown, with thin, whitish sapwood.

DISTRIBUTION.—Common throughout Vermont.

HABITAT.—Banks of streams and ponds; lake-shores.

NOTES.—The black willow is a slender, rather graceful tree, common everywhere along the banks of lakes and streams. It may be recognized usually by its stouter dark brown or black twigs in contrast with the more slender, yellowish or bluish-green twigs of the European species. When the pendulous catkins open, three to five or more stamens may be found in each tiny flower. The leaves are green when mature and smooth except on the mid veins and petioles. The branchlets are very brittle at the base, and these, broken off by the wind, are carried down stream, often catching in the muddy banks and there taking root.

Crack Willow



(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x 1.
4. Staminate flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flowering branchlet, x $\frac{1}{2}$.
7. Pistillate flower, enlarged.
8. Fruiting branchlet, x $\frac{1}{2}$.

SALICACEAE**Crack Willow*****Salix fragilis* L.**

HABIT.—A tree 50-60 feet high, with a short, stout trunk 3-4 feet in diameter; stout, spreading branches form a broad, open crown.

LEAVES.—Alternate, simple, 3-6 inches long, $\frac{1}{2}$ -1 $\frac{1}{2}$ inches broad; lanceolate, long-pointed; finely glandular-serrate; thin and firm; lustrous, dark green above, paler beneath, glabrous both sides; petioles short, stout, with 2 glands at the junction of blade and petiole.

FLOWERS.—May, with the leaves; dioecious; borne in slender, pubescent catkins 1-3 inches long; calyx 0; corolla 0; scales blunt, somewhat pubescent; stamens usually 2; ovary abortive, with stigmas nearly sessile. Staminate trees rare.

FRUIT.—May-June; 1-celled, long-conical, short-stalked capsule, about $\frac{1}{4}$ inch long, containing many minute seeds which are furnished with long, silky, white hairs.

WINTER-BUDS.—Terminal bud absent; lateral buds long-conical, pointed, glabrous, bright red-brown, about $\frac{1}{4}$ inch long.

BARK.—Twigs pubescent, yellow-green, often reddish, becoming glabrous, lustrous, brown; thick, gray on the trunk, smooth in young trees, very rough, irregularly scaly-ridged in old trees.

WOOD.—Light, soft, tough, close-grained, red-brown, with thick, whitish sapwood.

NOTES.—This willow is a native of Europe and Asia, where it is a valuable timber tree. It is commonly cultivated and frequently escapes. The crack willow is hardy throughout Vermont, of very rapid growth, and thrives in rich, damp soil. The twigs are very brittle at the base and are broken easily by the wind, hence the name "crack willow."

THE POPLARS

The genus *Populus* belongs to the willow family and resemble the willows, especially in flower and fruit characters. The nodding, worm-like, staminate and pistillate catkins are borne upon different trees, and opening before the leaves, are conspicuous in early spring. The poplars are distributed quite widely, extending from the Arctic Circle to Mexico and from the Atlantic to the Pacific.

The wood of poplars is very soft and light and especially liable to warp, but is cheap and useful for making toys, boxes and smaller furniture. Much of it now goes to the pulp mills.

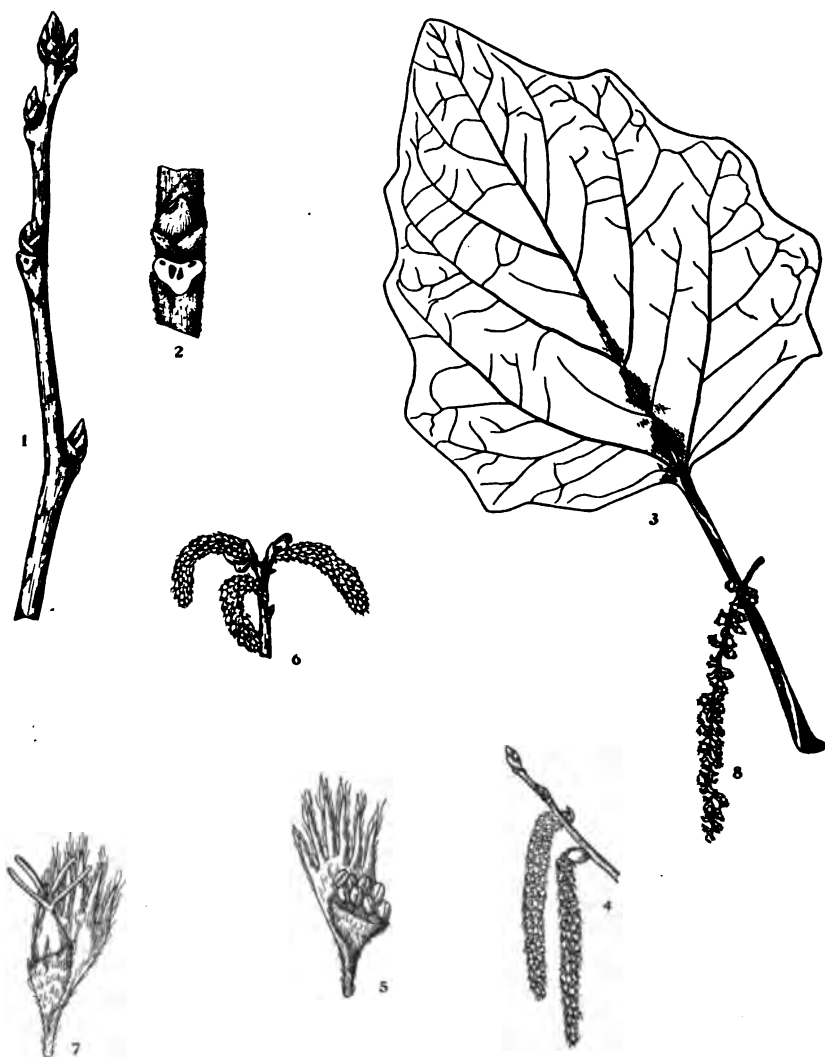
SUMMER KEY TO THE SPECIES OF POPULUS

- a. Leaf-petioles essentially terete.
 - b. Petioles and lower sides of leaves pubescent; leaves heart-shaped **P. candicans**, p. 71.
 - bb. Petioles and lower sides of leaves glabrous; leaves ovate-lanceolate **P. balsamifera**, p. 69.
- aa. Leaf-petioles strongly flattened.
 - b. Petioles and lower sides of leaves tomentose; twigs pubescent, **P. alba**, p. 63.
 - bb. Petioles and lower sides of leaves glabrous; twigs glabrous.
 - c. Leaves distinctly deltoid in shape.
 - d. Leaves broader than they are long, abruptly acuminate at the apex; marginal teeth not conspicuously incurved; branches erect and more or less appressed to the main stem, forming a narrow, spire-like crown. **P. nigra italica**, p. 75.
 - dd. Leaves longer than they are broad, more or less taper-pointed at the apex; marginal teeth rather conspicuously incurved; branches spreading, forming a broad crown. **P. deltoides**, p. 73.
 - cc. Leaves ovate to nearly orbicular in shape.
 - d. Margin of leaves coarsely sinuate-toothed; leaves 3-5 inches long **P. grandidentata**, p. 67.
 - dd. Margin of leaves finely serrate; leaves less than 3 inches long **P. tremuloides**, p. 65.

WINTER KEY TO THE SPECIES OF *POPULUS*

- a. Branches erect, more or less appressed to the main stem, forming a narrow, spire-like crown.....**P. nigra italica**, p. 75.
- aa. Branches spreading, forming a broad crown.
 - b. Terminal buds $\frac{1}{8}$ - $\frac{1}{4}$ inch long, not resinous.
 - c. Buds and twigs more or less conspicuously white-downy; twigs green**P. alba**, p. 63.
 - cc. Buds and twigs not conspicuously white-downy; twigs usually red-brown.
 - d. Terminal buds about $\frac{1}{8}$ inch long, puberulous, dusty-looking; lateral buds widely divergent; twigs rather coarse**P. grandidentata**, p. 67.
 - dd. Terminal buds about $\frac{1}{4}$ inch long, glabrous, lustrous; lateral buds more or less appressed; twigs rather slender,
P. tremuloides, p. 65.
 - bb. Terminal buds $\frac{1}{2}$ -1 inch long, sticky-resinous.
 - c. Terminal buds about $\frac{1}{2}$ inch long; buds not fragrant; twigs usually yellow, more or less strongly angled,
P. deltoides, p. 73.
 - cc. Terminal buds nearly 1 inch long; buds fragrant; twigs usually red-brown and seldom strongly angled,
P. balsamifera,¹ p. 69.
P. candicans,¹ p. 71.

¹ It is difficult to distinguish between these species in the absence of summer characters. If leaves can be found on or beneath a tree which is sufficiently segregated from similar trees as to avoid any chance for error, the summer key on the opposite page may be used.

White Poplar. Silver-leaved Poplar

(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x 2.
4. Staminate flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flowering branchlet, x $\frac{1}{2}$.
7. Pistillate flower, enlarged.
8. Fruit, x $\frac{1}{2}$.

SALICACEAE**White Poplar. Silver-leaved Poplar*****Populus alba* L.**

HABIT.—A large tree 50-75 feet high, with a trunk diameter of 2-4 feet, forming a large, spreading, rounded or irregular crown of large, crooked branches and sparse, stout branchlets.

LEAVES.—Alternate, simple, 2-4 inches long and almost as broad; broadly ovate to suborbicular; irregularly toothed, sinuate, or sometimes 3-5-lobed; glabrous, dark green above, white-tomentose to glabrous beneath; petioles long, slender, flattened, tomentose.

FLOWERS.—April-May, before the leaves; dioecious; the staminate catkins thick, cylindrical, 2-4 inches long; the pistillate catkins slender, 1-2 inches long; calyx 0; corolla 0; stamens 6-16, with purple anthers; stigmas 2, yellow.

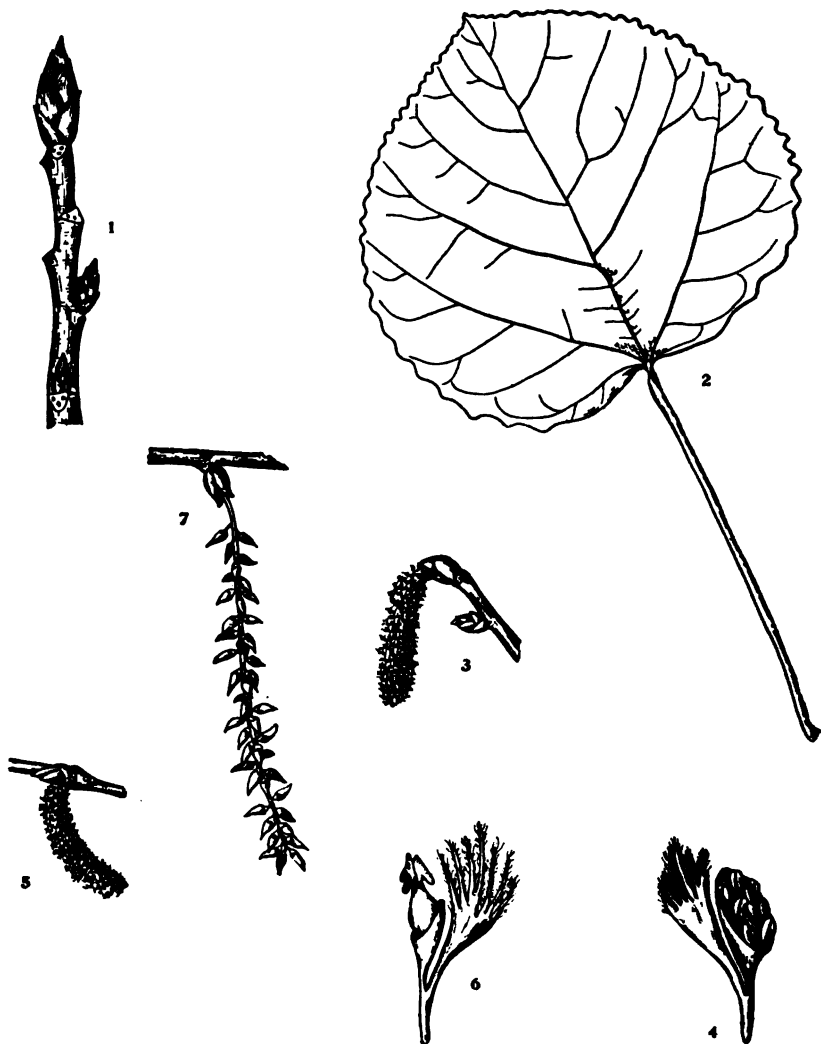
FRUIT.—May-June; ovoid, 2-valved capsules, $\frac{1}{8}$ - $\frac{1}{4}$ inch long, borne in drooping catkins 2-4 inches long; seeds light brown, surrounded by long, white hairs.

WINTER-BUDS.—Ovoid, pointed, not viscid, downy, about $\frac{1}{4}$ inch long.

BARK.—Twigs greenish, covered with a white down, becoming greenish gray and marked with darker blotches; dark gray and fissured at the base of old trunks.

WOOD.—Light, soft, weak, difficult to split, reddish yellow, with thick, whitish sapwood.

NOTES.—The white poplar is a native of Europe and Asia. It is hardy in Vermont, and is cultivated frequently, occasionally becoming an escape. It grows rapidly in good soils but thrives also in poor soils and in exposed situations. The deep roots produce numerous suckers for a considerable distance from the tree.

American Aspen. Trembling Poplar. Popple

(Mich. Trees).

1. Winter twig, x 2.
2. Leaf, x 1.
3. Staminate flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flowering branchlet, x $\frac{1}{2}$.
6. Pistillate flower, enlarged.
7. Fruit, x $\frac{1}{2}$.

SALICACEAE

American Aspen. Trembling Poplar. Popple

***Populus tremuloides* Michx.**

HABIT.—A small, slender tree generally 35-45 feet high, with a trunk diameter of 8-15 inches; forming a loose, rounded crown of slender branches.

LEAVES.—Alternate, simple, $1\frac{1}{2}$ - $2\frac{1}{2}$ inches long and broad; broadly ovate to suborbicular; finely serrate; thin and firm; lustrous, dark green above, dull and pale beneath; petioles slender, laterally compressed. Tremulous with the slightest breeze.

FLOWERS.—April, before the leaves; dioecious; the staminate catkins $1\frac{1}{2}$ -3 inches long, the pistillate at first about the same length, gradually elongating; calyx 0; corolla 0; stamens 6-12; stigmas 2, 2-lobed, red.

FRUIT.—May-June; 2-valved, oblong-cylindrical, short-pedicelled capsules $\frac{1}{4}$ inch long; seeds light brown, white-hairy.

WINTER-BUDS.—Terminal bud about $\frac{1}{4}$ inch long, narrow-conical. acute, red-brown, lustrous; lateral buds often appressed.

BARK.—Twigs very lustrous, red-brown, becoming grayish and roughened by the elevated leaf-scars; thin, yellowish or greenish and smooth on the trunk, often roughened with darker, horizontal bands or wart-like excrescences, becoming thick and fissured, almost black at the base of old trunks.

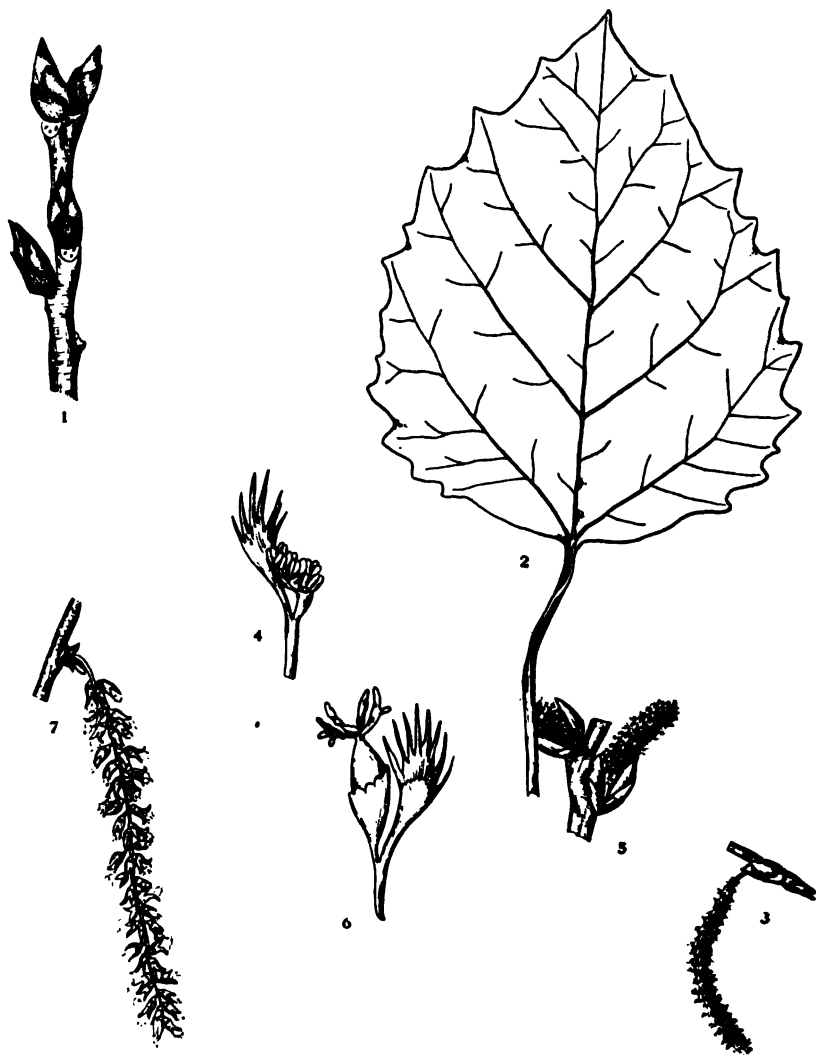
WOOD.—Light, soft, weak, close-grained, not durable, light brown, with thin, whitish sapwood. Page 229.

DISTRIBUTION.—Common throughout Vermont.

HABITAT.—Prefers moist, sandy soil and gravelly hillsides.

NOTES.—The most careless observer cannot have failed to notice the leaves of the aspen continually trembling on the quietest summer day. This tremulousness, indeed, has given name to the species. The reason for it, as may be seen readily by examination of any leaf, lies in the decidedly flattened structure of the leaf-stem or petiole. The slender drooping catkins appear in early spring and the downy fruits ripen in the latter part of May. The American aspen grows to a medium size, and is the most widely distributed tree in North America, extending from Labrador to Alaska, from Lower California to the Atlantic coast.

Large-toothed Aspen



(Mich. Trees).

1. Winter twig, $\times 2$.
2. Leaf, $\times 1$.
3. Staminate flowering branchlet, $\times \frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flowering branchlet, $\times \frac{1}{2}$.
6. Pistillate flower, enlarged.
7. Fruit, $\times \frac{1}{2}$.

SALICACEAE**Large-toothed Aspen*****Populus grandidentata* Michx.**

HABIT.—A medium-sized tree 30-50 feet high, with a slender trunk 12-20 inches in diameter; forming a loose, oval or rounded crown of slender, spreading branches and coarse spray.

LEAVES.—Alternate, simple, 3-5 inches long, two-thirds as broad; orbicular-ovate; coarsely and irregularly sinuate-toothed; thin and firm; dark green above, paler beneath, glabrous both sides; petioles long, slender, laterally compressed.

FLOWERS.—April-May, before the leaves; dioecious; the staminate in short-stalked catkins 1-3 inches long; the pistillate in loose-flowered, long-stalked catkins at first about the same length, but gradually elongating; calyx 0; corolla 0; stamens 6-12, with red anthers; stigmas 2, 2-lobed, red.

FRUIT.—May-June; 2-valved, conical, acute, hairy capsules $\frac{1}{8}$ inch long, borne in drooping catkins 4-6 inches long; seeds minute, dark brown, hairy.

WINTER-BUDS.—Terminal bud $\frac{1}{8}$ inch long, ovoid to conical, acute, light chestnut, puberulous, dusty-looking.

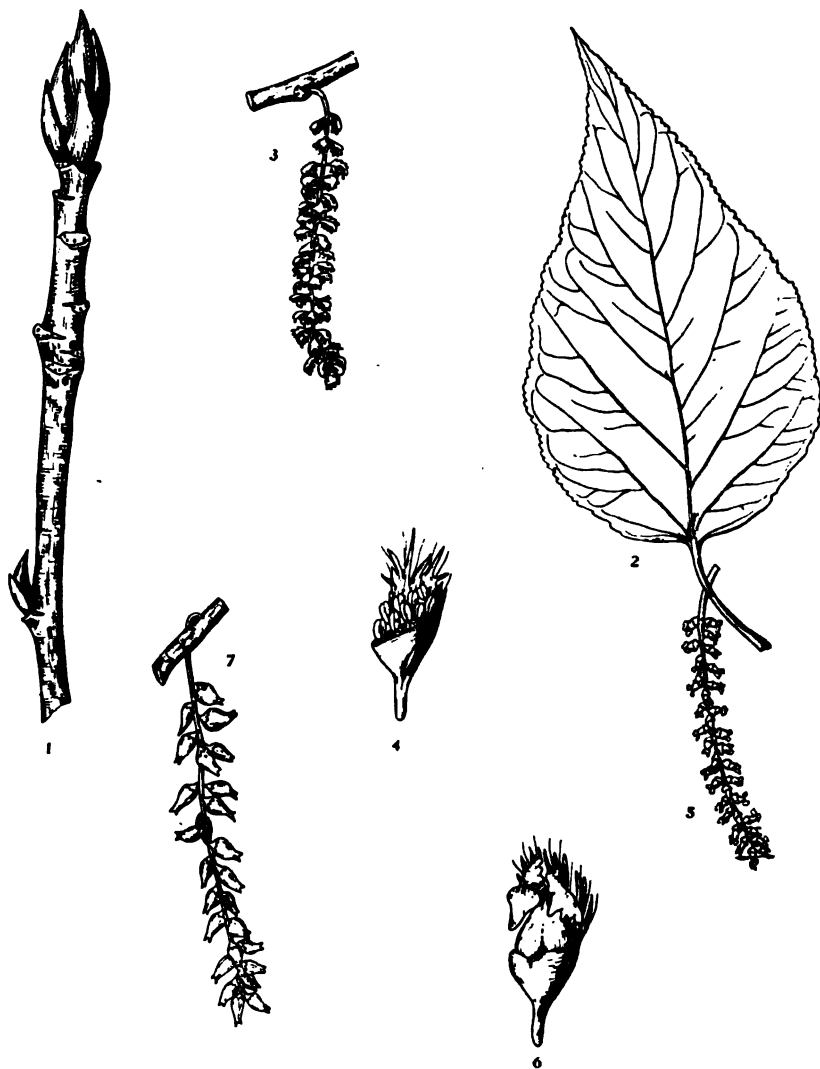
BARK.—Twigs greenish gray and at first hoary-tomentose, becoming lustrous, orange or red-brown and finally greenish gray; thick, dark red-brown or blackish at the base of old trunks, irregularly fissured, with broad, flat ridges.

WOOD.—Light, soft, weak, close-grained, light brown, with thin, whitish sapwood.

DISTRIBUTION.—Frequent throughout Vermont.

HABITAT.—Prefers rich, moist, sandy soil; rich woods.

NOTES.—The name of this tree suggests an easy way of identifying it. The coarse-toothed margin of the leaf is a constant characteristic and may be relied upon. The pollen-bearing catkins are seen first, the ovule-bearing catkins appearing a little later on other trees. The fruits ripen when the leaves are unfolding. The young leaves are downy-white on both sides, but later become green and smooth.

Balsam Poplar. Tacamahac

(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{3}{4}$.
3. Staminate flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Catkin of pistillate flower, x $\frac{1}{2}$.
6. Pistillate flower, enlarged.
7. Fruit, x $\frac{1}{2}$.

SALICACEAE**Balsam Poplar. Tacamahac*****Populus balsamifera* L.**

HABIT.—A tree 50-75 feet high, with a trunk diameter of 1-3 feet; forming a rather narrow, open, pyramidal crown of few, slender, horizontal branches.

LEAVES.—Alternate, simple, 3-6 inches long, about one-half as broad; ovate to ovate-lanceolate; finely crenate-serrate; thin and firm; lustrous, dark green above, paler beneath; petioles $1\frac{1}{2}$ inches long, slender, terete, smooth.

FLOWERS.—April-May, before the leaves; dioecious; the staminate in long-stalked catkins 3-4 inches long; the pistillate in loose-flowered, long-stalked catkins 4-5 inches long; calyx 0; corolla 0; stamens 20-30, with bright red anthers; ovary short-stalked; stigmas 2, wavy-margined.

FRUIT.—May-June; 2-valved, ovoid, short-pedicelled capsules $\frac{1}{4}$ inch long, borne in drooping catkins 4-6 inches long; seeds light brown, hairy.

WINTER-BUDS.—Terminal bud about 1 inch long, ovoid, long-pointed, brownish, resin-coated, sticky, fragrant.

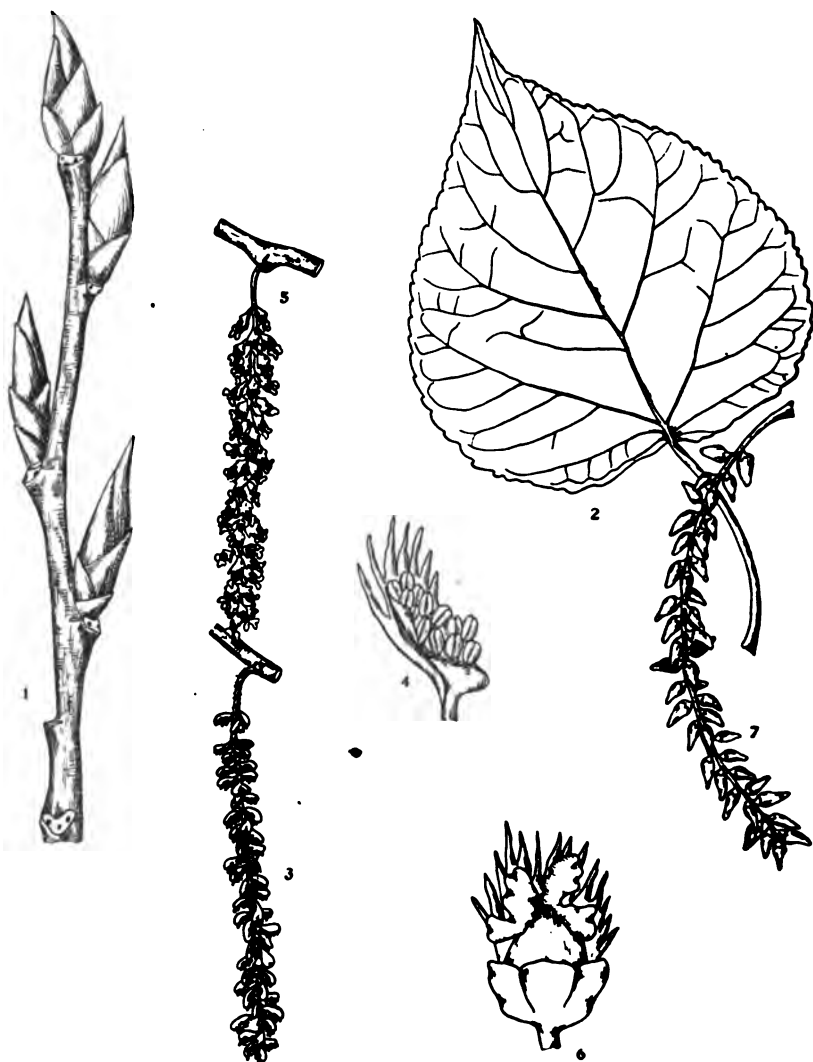
BARK.—Twigs red-brown, becoming dark orange, finally green-gray; thick, grayish on old trunks, and shallowly fissured into broad, rounded ridges, often roughened by dark excrescences.

WOOD.—Light, soft, weak, close-grained, light red-brown, with thick, nearly white sapwood.

DISTRIBUTION.—Frequent throughout Vermont; often planted as a shade tree.

HABITAT.—Borders of streams and swamps; wet ravines.

NOTES.—This tree is a northern species ranging from northern New England to the Alaskan coast. It is subject to great variation in the form of the leaves. Some are almost triangular with a deeply heart-shape base, while others are very slender with a wedge-shape base. The buds and young leaves are covered with a gummy excretion which sometimes is soaked out and used in preparing ointments. It is often confused with *P. candicans*, p. 71.

Balm of Gilead

(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{2}$.
3. Staminate flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flowering branchlet, x $\frac{1}{2}$.
6. Pistillate flower, enlarged.
7. Fruit, x $\frac{1}{2}$.

SALICACEAE

Balm of Gilead

Populus candicans Ait. [*Populus balsamifera candicans* (Ait.) Gray]

HABIT.—A tree 50-70 feet high, with a trunk diameter of 1-3 feet; more spreading branches than in *P. balsamifera*, forming a broader and more open crown.

LEAVES.—Resemble those of *P. balsamifera*, but more broadly heart-shaped and more coarsely serrate; more or less pubescent when young; petioles pubescent.

FLOWERS.—Similar to those of *P. balsamifera*.

FRUIT.—Similar to that of *P. balsamifera*.

WINTER-BUDS.—Terminal bud about 1 inch long, ovoid, long-pointed, dark red-brown, resinous throughout, viscid, very aromatic.

BARK.—Twigs reddish or olive-green, with occasional longitudinal gray lines, covered with a fragrant, gummy secretion, becoming gray-green; dark gray, rough, irregularly striate and firm on old trunks.

WOOD.—Resembles that of *P. balsamifera*, but is somewhat heavier.

NOTES.—The Balm of Gilead occasionally is cultivated and sometimes escapes to the roadsides. It was long confused with *P. balsamifera*. Further investigation may show it to be a native along our northern border. It grows rapidly in all soils and situations and spreads rapidly by suckers from the roots.

Cottonwood. Necklace Poplar



(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{2}$.
3. Staminate flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate catkin, x $\frac{1}{2}$.
6. Pistillate flower, enlarged.
7. Fruit, x $\frac{1}{2}$.

SALICACEAE**Cottonwood. Necklace Poplar**

Populus deltoides Marsh. [*Populus monilifera* Ait.]

HABIT.—A stately tree attaining a height of 70-90 feet and a trunk diameter of 3-5 feet; forming a spreading, open, symmetrical crown of massive, horizontal branches and stout, more or less angled branchlets.

LEAVES.—Alternate, simple, 3-6 inches long, nearly as broad; broadly deltoid-ovate; coarsely crenate-serrate above the entire base; thick and firm; lustrous, dark green above, paler beneath; petioles 2-3 inches long, slender, compressed laterally.

FLOWERS.—April-May, before the leaves; dioecious; the staminate in short-stalked, densely-flowered catkins 3-4 inches long; the pistillate in short-stalked, few-flowered catkins elongating to 6-8 inches; calyx 0; corolla 0; stamens very numerous, with red anthers; stigmas 3-4, spreading.

FRUIT.—May; 2-4-valved, short-stalked capsules, borne in drooping catkins 5-10 inches long; seeds light brown, densely cottony.

WINTER-BUDS.—Terminal bud $\frac{1}{2}$ inch long, conical, acute, very resinous, shining, brownish.

BARK.—Twigs and young stems smooth, yellow-green; old trunks ashy gray, deeply divided into straight furrows with broad, rounded ridges.

WOOD.—Light, soft, weak, close-grained, dark brown, with thick, whitish sapwood; warps badly and is difficult to season.

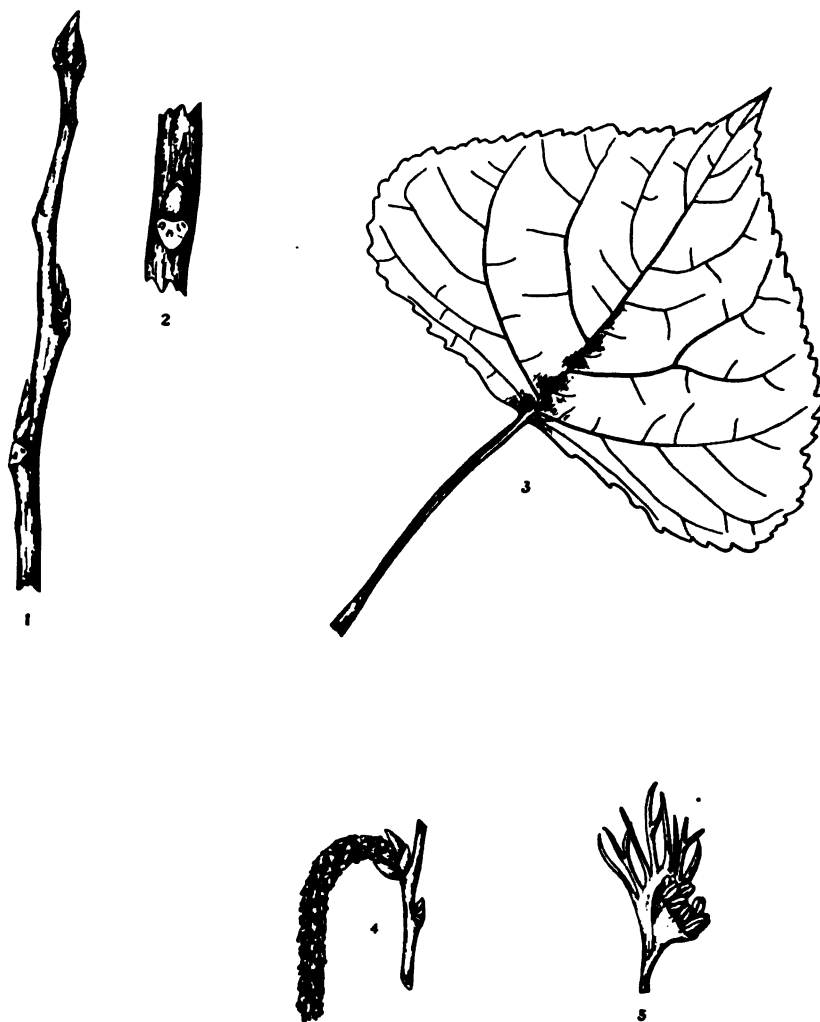
DISTRIBUTION.—Frequent in western Vermont.

HABITAT.—Prefers rich, moist soil, such as river-banks, river-bottoms or lake-shores; grows well in drier situations.

NOTES.—The cottonwood occurs native in the Champlain valley and along its tributary streams, and south in western Vermont to the Hoosic valley in Pownal, where it is particularly abundant. It occurs along the Connecticut river in southeastern Vermont at least as far north as Brattleboro. It has been planted as a shade tree in other localities usually under the name of "Carolina poplar." The stamen-bearing trees always should be chosen for this purpose since the abundant, cottony seed is a nuisance near dwellings.

The cottonwood is the most massive of our deciduous trees, sometimes reaching 100 feet in height and five to seven feet in diameter. Such isolated giants have become the familiar landmarks of many roadsides near Lake Champlain. It is a rapid-growing tree but short-lived and poorly adapted to street planting.

Lombardy Poplar



(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{3}{4}$.
4. Staminate flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.

SALICACEAE**Lombardy Poplar**

Populus nigra italica DuRoi [Populus fastigiata Desf.] [Populus dilatata Ait.]

HABIT.—A tree 75-100 feet high, with a short, ridged and buttressed trunk 4-6 feet in diameter and a narrow, spire-like crown of erect branches.

LEAVES.—Alternate, simple, 2-4 inches long, and usually somewhat broader than long; broad-deltoid, abruptly acuminate at the apex; finely but bluntly crenate-serrate; thick and firm; dark green and shining above, lighter and more or less lustrous beneath; petioles slender, laterally compressed, 1-2 inches long.

FLOWERS.—April-May, before the leaves; dioecious; the staminate in sessile, dark red, cylindrical catkins about 3 inches long; the pistillate not present in the United States; calyx 0; corolla 0; stamens about 8, with white filaments and purple anthers.

FRUIT.—Not formed in the United States in the absence of pistillate flowers.

WINTER-BUDS.—Terminal bud conical, slightly angled, taper-pointed, glutinous, about $\frac{3}{8}$ inch long; lateral buds smaller, appressed.

BARK.—Twigs glabrous, shining yellow, becoming gray; thick and gray-brown on old trunks, deeply and irregularly furrowed.

WOOD.—Light, soft, easily worked, not liable to splinter, weak, not durable, light red-brown, with thick, nearly white sapwood.

NOTES.—This tree is thought to be a native of Afghanistan. It is frequently cultivated in Vermont and tends to spread by sprouting from the roots. It is used for ornamental purposes on account of its very rapid growth; but it is short-lived, its limbs die early, and these remain, causing the tree to become unsightly in a very few years.

THE WALNUTS

Every school boy in Vermont has some acquaintance at least with the butternut and its sweet, tender nuts. It occurs along the hill-sides and river-valleys throughout the State. The staminate flowers appear in May and hang in graceful, slender catkins five or six inches long. These are generally found on the second-year shoots, while the pistillate flowers are borne on the terminal shoots. Butternut trees show some irregularities, however, in reference to the time and order of the appearance of the two kinds of flowers so that the pollen-bearing clusters may mature either some ten days earlier or later than the ovule-bearing ones on the same tree. This may be the cause of the variability often noticed in the crop of butternuts. The peculiarity offers an interesting subject for further observation.

The meat of the butternut needs no recommendation, but the excellencies of pickles made from the young mucilaginous nuts are not so well known. For this purpose they should be gathered early in June and the clammy pubescence removed by plunging them into boiling water and rubbing with a coarse cloth.

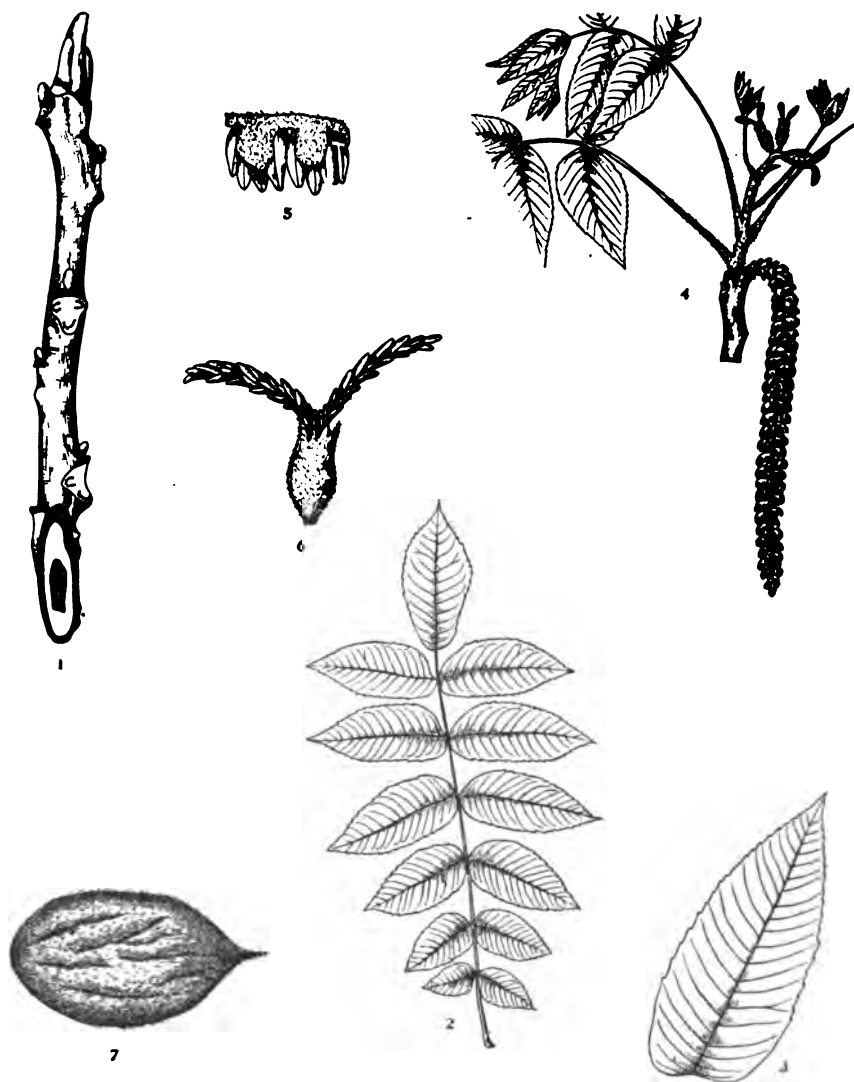
The other member of this family, the black walnut, is not known so well in Vermont. It is not a native tree in Vermont, although it occurs occasionally in Southern New England, becoming more abundant southward and westward. It is planted often for ornamental uses and is a much better tree for this purpose than our native walnut.

SUMMER KEY TO THE SPECIES OF JUGLANS

- a.* Leaflets 11-17, the terminal usually present; pith of twigs chocolate-brown; bark of trunk rather smooth, or fissured, with broad, flat, whitish ridges; fruit elongated, sticky-downy. . . **J. cinerea**, p. 79.
- aa.* Leaflets 13-23, the terminal often lacking; pith of twigs cream colored; bark of trunk rough, brownish or blackish, deeply furrowed by broad, rounded ridges; fruit globose, not sticky-downy,
J. nigra, p. 81.

WINTER KEY TO THE SPECIES OF JUGLANS

- a.* Pith chocolate-brown; leaf-scar with downy pad above; fruit elongated, sticky-downy; terminal bud $\frac{1}{2}$ - $\frac{3}{4}$ inch long; bark rather smooth, or fissured, with broad, flat, whitish ridges,
J. cinerea, p. 79.
- aa.* Pith cream colored; leaf-scar without downy pad above; fruit globose, not sticky-downy; terminal bud $\frac{1}{3}$ inch long; bark rough, brownish or blackish, deeply furrowed by broad, rounded ridges,
J. nigra, p. 81.

Butternut

(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{6}$.
3. Leaflet, x $\frac{1}{2}$.
4. Flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flower, enlarged.
7. Fruit, x $\frac{1}{2}$.

JUGLANDACEAE**Butternut*****Juglans cinerea* L.**

HABIT.—A medium-sized tree 30-50 feet high, with a short trunk 2-3 feet in diameter; forming a wide-spreading crown of large, horizontal branches and stout, stiff branchlets.

LEAVES.—Alternate, compound, 15-30 inches long. Leaflets 11-17, 2-4 inches long and one-half as broad; sessile, except the terminal; oblong-lanceolate; finely serrate; thin; yellow-green and rugose above, pale and soft-pubescent beneath. Petioles stout, hairy.

FLOWERS.—May, with the leaves; monoecious; the staminate in cylindrical, greenish, drooping catkins 3-5 inches long; calyx 6-lobed, borne on a hairy bract; corolla 0; stamens 8-12, with brown anthers; the pistillate solitary or several on a common peduncle, about $\frac{1}{3}$ inch long, their bracts and bractlets sticky-hairy; calyx 4-lobed, hairy; corolla 0; styles 2; stigmas 2, fringed, spreading, bright red.

FRUIT.—October; about $2\frac{1}{2}$ inches long, cylindrical, pointed. greenish, sticky-downy, solitary or borne in drooping clusters of 3-5; nuts with rough shells, inclosing a sweet, but oily kernel; edible.

WINTER-BUDS.—Terminal bud $\frac{1}{2}$ - $\frac{3}{4}$ inch long, oblong-conical, obliquely blunt, somewhat flattened, brownish, pubescent.

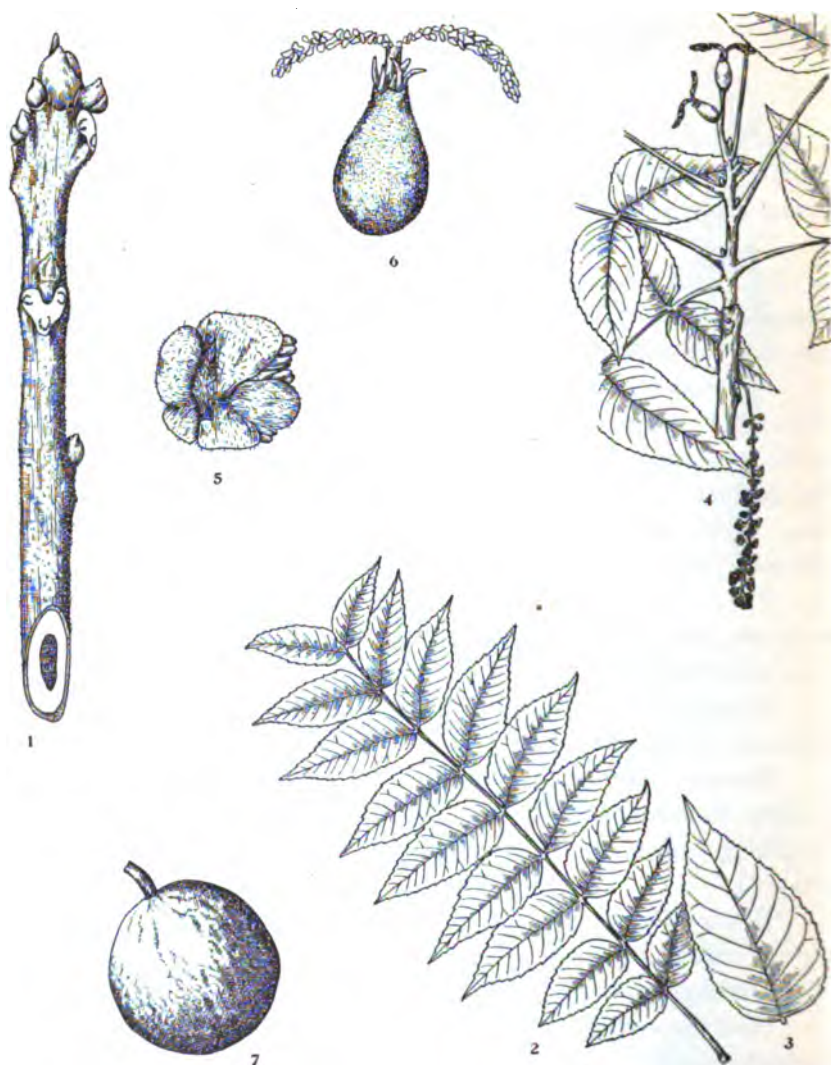
BARK.—Twigs orange-brown or bright green, rusty-pubescent, becoming smooth and light gray; gray and smoothish on young trunks, becoming brown on old trunks, narrow-ridged, with wide furrows. Plate II.

WOOD.—Light, soft, weak, coarse-grained, light brown, with thin, lighter colored sapwood.

DISTRIBUTION.—Of frequent occurrence throughout Vermont.

HABITAT.—Prefers low, rich woods; river-banks; low hillsides; rocky hillsides.

NOTES.—The leaves of the butternut appear late and fall early. The young trees are very attractive but the larger trees usually are scraggy and unsound. Some preliminary work done in Dorset, Bennington County, seems to indicate that perhaps through some peculiar root antagonism the butternut will kill the shrubby cinquefoil (*Potentilla fruticosa*), a shrub which is destroying some of the best pastures in Northwestern Connecticut, Berkshire County, Massachusetts and Bennington and Rutland Counties, Vermont.

Black Walnut

(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{6}$.
3. Leaflet, x $\frac{1}{2}$.
4. Flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, back view, enlarged.
6. Pistillate flower, enlarged.
7. Fruit, x $\frac{1}{2}$.

JUGLANDACEAE**Black Walnut*****Juglans nigra* L.**

HABIT.—A large tree 50-75 feet high, with a massive trunk 2-5 feet in diameter; forming an open, capacious crown of heavy branches and coarse branchlets.

LEAVES.—Alternate, compound, 1-2 feet long. Leaflets 13-23, the terminal often lacking, 2-4 inches long and one-half as broad; sessile; ovate-lanceolate, taper-pointed; sharp-serrate; thin; yellow-green and glabrous above, lighter and soft-pubescent beneath. Petioles stout, pubescent. Foliage aromatic when bruised.

FLOWERS.—May, with the leaves; monoecious; the staminate in cylindrical, greenish, drooping catkins 3-5 inches long; calyx 6-lobed, borne on a hairy bract; corolla 0; stamens numerous, with purple anthers; the pistillate solitary or several on a common peduncle, about $\frac{1}{4}$ inch long, their bracts and bractlets hairy; calyx 4-lobed, pubescent; corolla 0; styles and stigmas 2.

FRUIT.—October; globose, $1\frac{1}{2}$ -2 inches in diameter, smooth, not viscid; solitary or borne in clusters of 2-3; nuts with irregularly furrowed shell, inclosing a sweet, edible kernel; aromatic.

WINTER-BUDS.—Terminal bud $\frac{1}{3}$ inch long, ovoid, obliquely blunt, slightly flattened, silky-tomentose.

BARK.—Twigs brownish and hairy, becoming darker and smooth; thick, brownish or blackish on the trunk and deeply furrowed by broad, rounded ridges.

WOOD.—Heavy, hard, strong, close-grained, very durable in contact with the soil, rich dark brown, with thin, lighter colored sapwood.

NOTES.—The black walnut was once very abundant, especially in the Mississippi basin, where it grew to a height of 150 feet. It is valued for its nuts and beautiful wood. It prefers rich bottom-lands and fertile hillsides. The leaves appear late and fall early. One great drawback to its use in ornamental planting is the fact that it is so often infested with caterpillars.

THE HICKORIES

The hickories are stately trees, quite generally distributed throughout the United States. There are eight species, all peculiar to America, several of which produce edible nuts. Among the latter are the shell-bark hickory in the north and the pecan in the south.

The flowers, arranged in catkins of the two kinds, appear in late spring after the unfolding of the leaves.

The wood of all these trees is heavy, tough and durable. It is used for axe handles, agricultural implements, and in places where strength and elasticity are required it is almost unrivaled.

The hickories frequently but erroneously are termed "walnuts" in the popular language of New England. The true walnuts, of which the butternut and black walnut are the American representatives, differ from the hickories, although they are closely related.

SUMMER KEY TO THE SPECIES OF CARYA

- a. Bark of trunk essentially smooth, not deeply furrowed nor shaggy; husk of fruit less than $\frac{1}{8}$ inch thick.
 - b. Leaflets usually 5-7, glabrous beneath, the upper 2-2½ inches broad; buds dome-shaped, greenish; kernel of nut sweet,
 - C. glabra**, p. 89.
 - bb. Leaflets usually 7-11, more or less downy beneath, the upper 1-1½ inches broad; buds long-pointed, flattish, bright yellow; kernel of nut bitter **C. cordiformis**, p. 91.
- aa. Bark of trunk deeply furrowed or shaggy; husk of fruit more than $\frac{1}{8}$ inch thick.
 - b. Twigs more or less pubescent; bark not shaggy; leaflets 5-7, more or less pubescent beneath; buds densely hairy,
 - C. alba**, p. 87.
 - bb. Twigs tending to be glabrous; bark distinctly shaggy; leaflets usually 5, glabrous beneath; buds glabrous or nearly so,
 - C. ovata**, p. 85.

WINTER KEY TO THE SPECIES OF CARYA

- a. Bark of trunk essentially smooth, not deeply furrowed nor shaggy; husk of fruit less than $\frac{1}{8}$ inch thick.
 - b. Terminal bud narrow, long-pointed, flattish, bright yellow, about $\frac{3}{4}$ inch long; kernel of nut bitter **C. cordiformis**, p. 91.
 - bb. Terminal bud broad, dome-shaped, greenish, $\frac{1}{4}$ -½ inch long; kernel of nut sweet **C. glabra**, p. 89.
- aa. Bark of trunk deeply furrowed or shaggy; husk of fruit more than $\frac{1}{8}$ inch thick.
 - b. Twigs more or less pubescent; buds densely hairy, the outer bud-scales deciduous in autumn; bark not shaggy. . **C. alba**, p. 87.
 - bb. Twigs tending to be glabrous; buds glabrous or nearly so, the outer bud-scales not deciduous in autumn; bark distinctly shaggy **C. ovata**, p. 85.

Shellbark Hickory. Shagbark Hickory

(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{1}{3}$.
4. Flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flower, enlarged.
7. Fruit, x $\frac{1}{2}$.

JUGLANDACEAE

Shellbark Hickory. Shagbark Hickory

Carya ovata (Mill.) K. Koch [*Hicoria ovata* (Mill.) Britt.]
[*Carya alba* Nutt.]

HABIT.—A tree 50-75 feet high, with a slender, columnar trunk 1-2 feet in diameter; forming a narrow, somewhat open crown of stout, slightly spreading limbs and stout branchlets.

LEAVES.—Alternate, compound, 8-14 inches long. Leaflets usually 5, the upper 5-7 inches long and 2-3 inches broad; sessile, except the terminal; obovate to oblong-lanceolate; finely serrate; thick and firm; glabrous, dark green above, paler beneath and glabrous or puberulous. Petioles stout, smooth or hairy. Foliage fragrant when crushed.

FLOWERS.—May-June, after the leaves; monoecious; the staminate hairy, greenish, in pendulous, ternate catkins 4-5 inches long, on a common peduncle about 1 inch long; scales 3-parted, bristle-tipped; stamens 4, with bearded, yellow anthers; the pistillate in 2-5-flowered spikes, $\frac{1}{3}$ inch long, brown-tomentose; calyx 4-lobed, hairy; corolla 0; stigmas 2, large, fringed.

FRUIT.—October; globular, 1-2 inches long, with thick husk separating completely; nut usually 4-ridged, with thick shell and large, sweet, edible kernel.

WINTER-BUDS.—Terminal bud $\frac{1}{2}$ - $\frac{3}{4}$ inch long, broadly ovoid, obtuse, dark brown, pale-tomentose or nearly glabrous.

BARK.—Twigs brownish, more or less downy, becoming smooth and grayish; thick and grayish on old trunks, separating into thick strips 1-3 feet long, free at one or both ends, giving a characteristic shaggy appearance. Plate II.

WOOD.—Heavy, very hard and strong, tough, close-grained, elastic, light brown, with thin, whitish sapwood. Page 229.

DISTRIBUTION.—Frequent in the lower altitudes west of the Green mountains; known in the Connecticut valley as far north as Bellows Falls; a large grove on the south side of Bald Mountain in Shrewsbury at an altitude of about 1,500 feet.

HABITAT.—Prefers light, well-drained, loamy soil; low hillsides; river-banks.

NOTES.—The shellbark hickory is one of our most attractive trees. It is known to every boy who lives in its range by its shaggy bark and its excellent nuts.

Mocker Nut. White Heart Hickory

(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{3}$.
3. Flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flower, enlarged.
6. Fruit, x $\frac{1}{2}$.

JUGLANDACEAE

Mocker Nut. White Heart Hickory

Carya alba (L.) K. Koch [*Hicoria alba* (L.) Britt.] [*Carya tomentosa* Nutt.]

HABIT.—A tree 50-70 feet high, with a trunk diameter of 1-2½ feet; forming a wide crown of strong, upright branches and stout branchlets.

LEAVES.—Alternate, compound, 8-12 inches long. Leaflets usually 5-7, sometimes 9, the upper 5-8 inches long, 3-4 inches broad; sessile, except the terminal; oblong- to obovate-lanceolate; minutely or sometimes coarsely serrate; thick and firm; lustrous, dark yellow-green above, paler and more or less pubescent beneath. Petioles pubescent. Foliage fragrant when crushed.

FLOWERS.—May-June, after the leaves; monoecious; the staminate in pendulous, ternate catkins 4-5 inches long, slender, green, hairy; scales 3-lobed, hairy; stamens 4-5, with red anthers; the pistillate in crowded, 2-5-flowered, tomentose spikes; calyx toothed, hairy; corolla 0; stigmas 2, hairy.

FRUIT.—October; globose to globose-oblong, 1½-2 inches long, with thick husk splitting nearly to the base; nut 4-ridged, red-brown, with very thick, hard shell and small, sweet kernel.

WINTER-BUDS.—Terminal bud ½-¾ inch long, broadly ovoid, red-brown, pilose; outermost scales fall in early autumn.

BARK.—Twigs at first brown-tomentose, becoming smooth and grayish; on the trunk thick, hard, grayish, slightly ridged by shallow, irregular fissures, becoming rugged on very old trunks.

WOOD.—Very heavy, hard, strong, tough, close-grained, elastic, dark brown, with thick, whitish sapwood.

DISTRIBUTION.—Reported from Burlington and West Haven; probably occurs in other localities in the lower altitudes of the southern half of the State.

HABITAT.—Prefers rich, well-drained soil, but grows well in various situations, if they are not too wet.

NOTES.—This tree probably is not distinguished by most observers from *C. ovata*, which it closely resembles; there is need of further and more thorough investigation of this species.

Pignut



(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{4}$.
3. Flowering branchlet, x 1.
4. Staminate flower, enlarged.
5. Pistillate flower, enlarged.
6. Fruit, x 1.

JUGLANDACEAE

Pignut

Carya glabra (Mill.) Spach. [*Hicoria glabra* (Mill.) Britt.]
[*Carya porcina* Nutt.]

HABIT.—A tree usually 50-60 feet high, with a trunk diameter of 1-3 feet; forming a low, rather narrow, open crown of slender, often contorted branches.

LEAVES.—Alternate, compound, 8-12 inches long. Leaflets usually 5-7, the upper 3-6 inches long, 2-2½ inches broad; sub-sessile, except the terminal; oblong to obovate-lanceolate, taper-pointed; sharply serrate; thick and firm; glabrous, dark yellow-green above, paler beneath. Petioles long, slender, glabrous or pubescent. Foliage fragrant when crushed.

FLOWERS.—May-June, after the leaves; monoecious; the staminate in pendulous, ternate catkins 3-7 inches long, slender, yellow-green, tomentose; scales 3-lobed, nearly glabrous; stamens 4, with orange anthers; the pistillate in crowded, 2-5-flowered spikes, ¼ inch long; calyx 4-toothed, hairy; corolla 0; stigmas 2, yellow.

FRUIT.—October; variable in size and shape, 1½-2 inches long, with thin husk splitting half-way and sometimes nearly to the base; nut obscurely 4-ridged, with thin or thick, hard shell and small, sweet or slightly bitter kernel which is hard to remove.

WINTER-BUDS.—Terminal bud ¼-½ inch long, dome-shaped, greenish or grayish, smooth or finely downy.

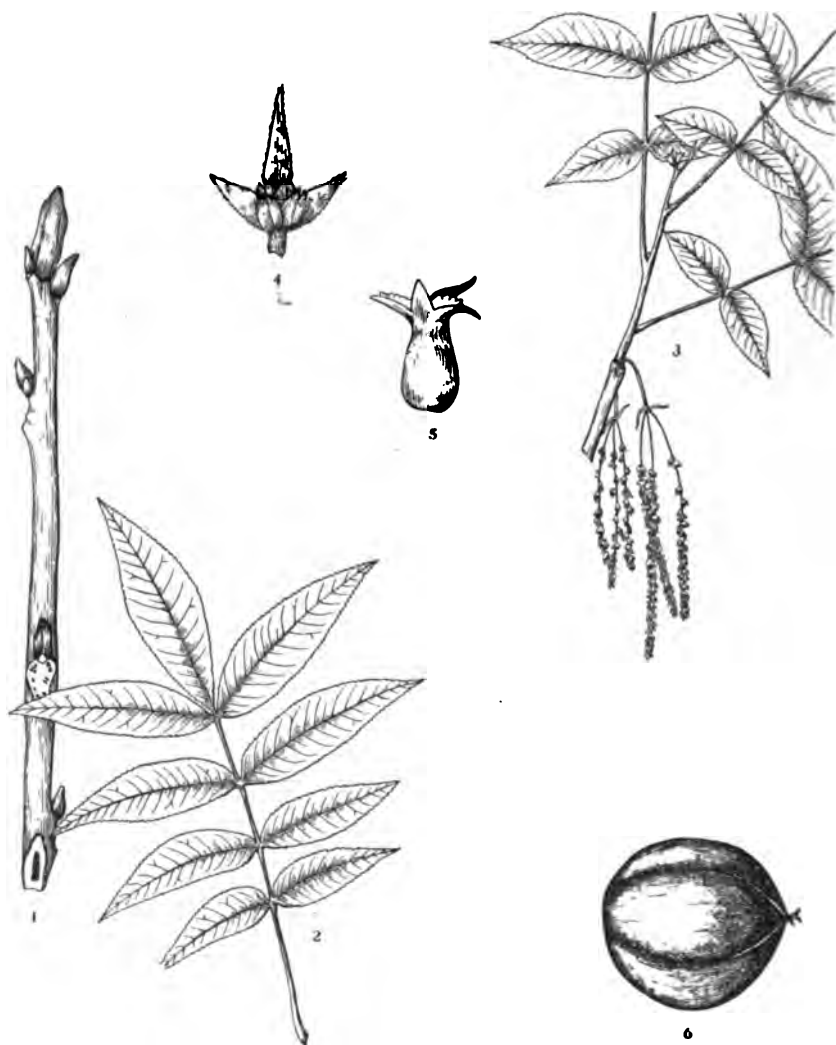
BARK.—Twigs greenish, nearly glabrous, becoming reddish, and finally grayish; thick, hard and grayish on the trunk, with a firm, close surface divided by small fissures and sometimes broken into plates. Plate II.

WOOD.—Heavy, hard, very strong, tough, close-grained, elastic, dark brown, with thick, whitish sapwood.

DISTRIBUTION.—Occurs in the southern portion of Vermont.

HABITAT.—Prefers deep, rich loam, but grows in any well-drained soil; dry ridges and hillsides.

NOTES.—This is a common tree in the Hoosic valley, Pownal, and a large grove occurs on the shore of Lake Bomoseen, West Castleton (Eggleston). There are a few trees near the Hubbardton line in East Castleton (G. H. Ross). In the Connecticut valley it is abundant on the hills near the river in the vicinity of the Massachusetts line, but is not common above Bellows Falls (Flint). Observers of trees in southern Vermont should strive further to increase our knowledge of its distribution.

Bitternut Hickory

(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{3}$.
3. Flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flower, enlarged.
6. Fruit, x 1.

JUGLANDACEAE

Bitternut Hickory

Carya cordiformis (Wang.) K. Koch [*Hicoria minima* (Marsh.) Britt.] [*Carya amara* Nutt.]

HABIT.—A tall, slender tree 50-75 feet high, with a trunk diameter of 1-2½ feet; forming a broad crown of slender, stiff, upright branches, widest near the top.

LEAVES.—Alternate, compound, 6-10 inches long. Leaflets 5-11, the upper 4-6 inches long and one-fourth as broad; sessile, except the terminal; lanceolate to oblong-lanceolate, long-pointed; coarsely serrate; thin and firm; glabrous, bright green above, paler and more or less downy beneath. Petioles slender, hairy. Foliage fragrant when crushed.

FLOWERS.—May-June, after the leaves; monoecious; the staminate slightly pubescent, in pendulous, ternate catkins 3-4 inches long, on a common peduncle about 1 inch long; scale 3-lobed, hairy; stamens 4, with bearded, yellow anthers; the pistillate in 2-5-flowered spikes, ½ inch long, scurfy-tomentose; calyx 4-lobed, pubescent; corolla 0; stigmas 2, greenish.

FRUIT.—October; obovate to globular, about 1 inch long, coated with yellow, scurfy pubescence, with very thin husk splitting half-way to the base, with sutures winged at the top; nut quite smooth, with thin shell and small, bitter kernel.

WINTER-BUDS.—Terminal bud about ¾ inch long, long-pointed, flattish, granular-yellow; lateral buds more or less 4-angled.

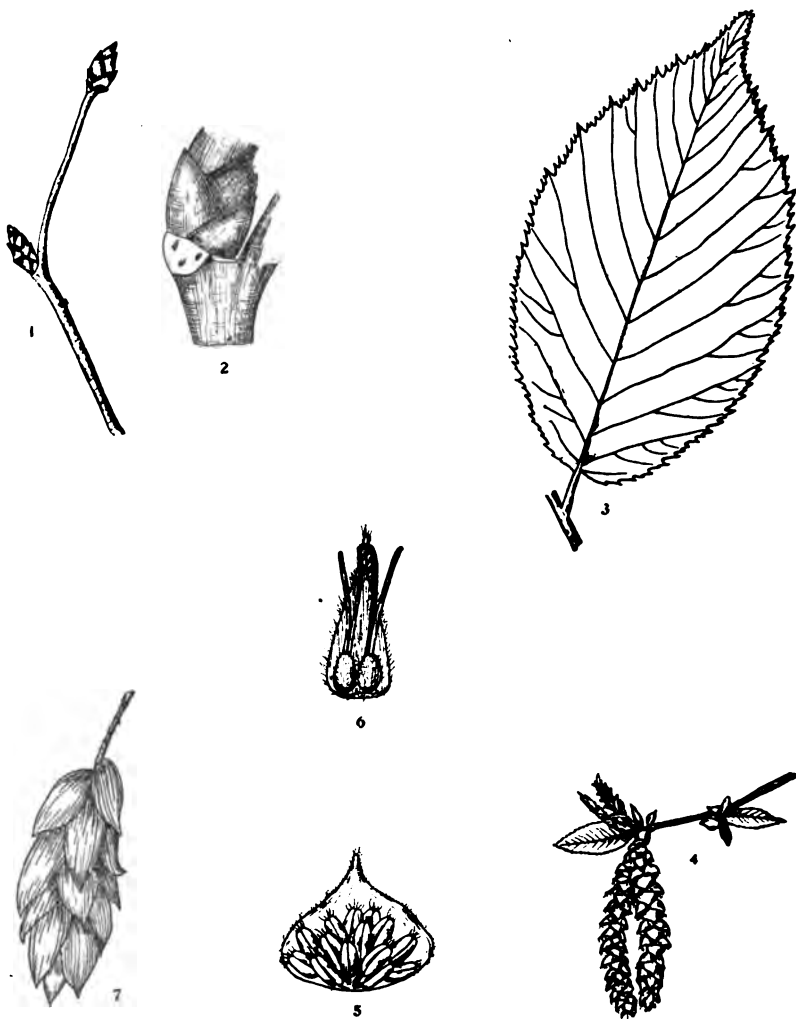
BARK.—Twigs greenish and more or less downy, becoming brownish, and finally grayish; gray, close, smooth on the trunk, often reticulately ridged, but rarely broken into plates. Plate III.

WOOD.—Heavy, very hard, strong, tough, close-grained, dark brown, with thick, lighter colored sapwood.

DISTRIBUTION.—Frequent in the lower altitudes west of the Green mountains and known in the Connecticut valley as far north as Hartland.

HABITAT.—Prefers a rich, loamy soil; low, wet woods; along the borders of streams.

NOTES.—The bitternut grows most rapidly of all the hickories, but it is apt to show dead branches. It should be propagated from the seed, as it is not easily transplanted. The yellow buds at once distinguish it from all other hickories.

American Hop Hornbeam. Leverwood

(Mich. Trees).

1. Winter twig, x $\frac{1}{2}$.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{1}{2}$.
4. Flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flower, enlarged.
7. Fruit, x $\frac{1}{2}$.

BETULACEAE**American Hop Hornbeam. Leverwood*****Ostrya virginiana* (Mill.) K. Koch**

HABIT.—A small tree usually 20-30 feet high, with a trunk diameter of 8-12 inches; forming a broad, rounded crown of many long, slender branches and a slender, stiff spray.

LEAVES.—Alternate, simple, 3-5 inches long, about one-half as broad; oblong-ovate; sharply doubly serrate; thin and very tough; dull, dark green above, paler and more or less pubescent beneath; petioles short, slender, pubescent.

FLOWERS.—May, with the leaves; monoecious; the staminate in drooping, cylindrical catkins from wood of the previous season, usually in threes; stamens 3-14, crowded on a hairy torus; the pistillate in erect, lax catkins on the season's shoots, usually in pairs, each flower inclosed in a hairy, sac-like involucre.

FRUIT.—September; strobiles, resembling clusters of hops, 1-2 inches long, borne on slender, hairy stems; nuts small and flat, inclosed by sac-like involucre.

WINTER-BUDS.—Terminal but absent; lateral buds $\frac{1}{8}$ - $\frac{1}{4}$ inch long, ovoid, acute, red-brown.

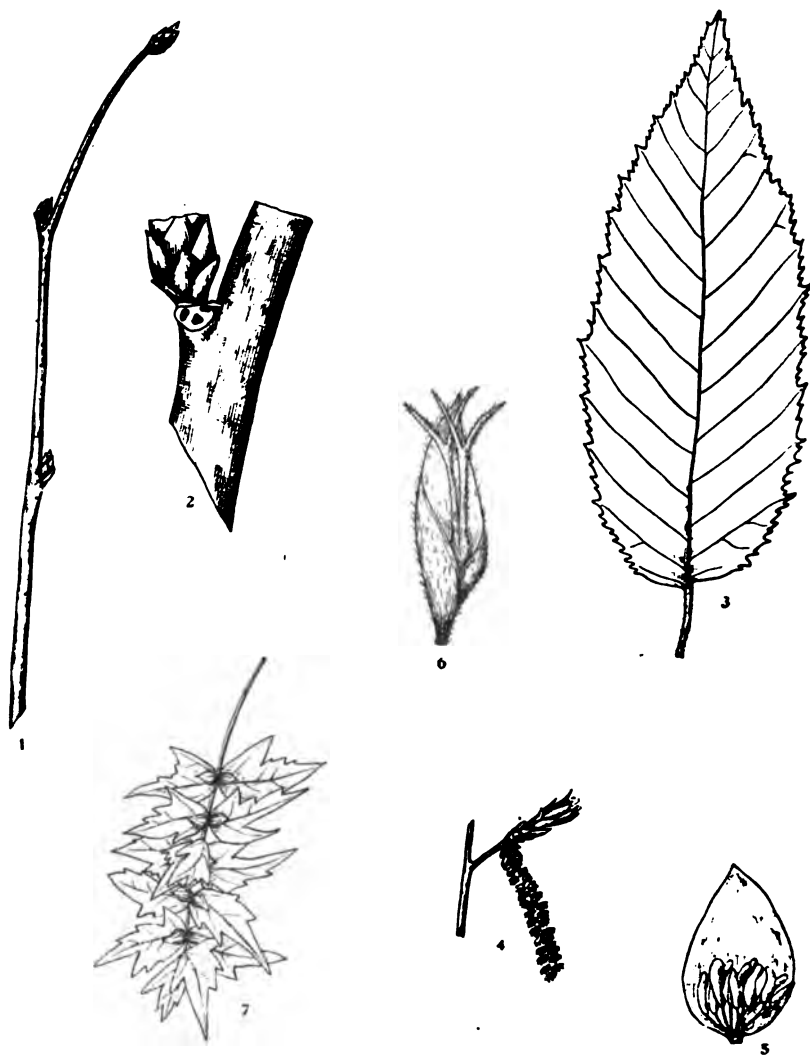
BARK.—Twigs at first light green, becoming lustrous, red-brown, and finally dull dark brown; thin, gray-brown on the trunk, very narrowly and longitudinally ridged. Plate III.

WOOD.—Heavy, very strong and hard, tough, close-grained, durable, light red-brown, with thick, whitish sapwood.

DISTRIBUTION.—Common to both valleys and mountains of Vermont, but more abundant in the western and southern portions.

HABITAT.—Rich woods; open woods; slopes and ridges.

NOTES.—Hornbeams sometimes are mistaken and transplanted for elms, owing to the general similarity in the appearances of the young trees. The leaves of the hornbeam, however, are nearly symmetrical at the base, while those of the elm are more unequally developed. In late summer the hornbeam is easily distinguished by its fruit hanging in hop-like heads. The hornbeam is distributed, quite generally, both in the valleys and the mountainous parts of Vermont, but is most common in western and southern portions. It is a small tree. The wood is very strong, tough and durable in contact with the soil, hence the names ironwood, leverwood. It is used for levers, mallets and for fencing materials.

American Hornbeam. Blue Beech. Water Beech

(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x 1.
4. Flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flower, enlarged.
7. Fruit, x $\frac{1}{2}$.

BETULACEAE**American Hornbeam. Blue Beech. Water Beech*****Carpinus caroliniana* Walt.**

HABIT.—Usually a low, bushy tree or large shrub, 10-30 feet high, with a trunk diameter of 6-12 inches; trunk short, usually fluted; slender zigzag branches and a fine spray form a close, flat-topped crown.

LEAVES.—Alternate, simple, 2-4 inches long and one-half as broad; ovate to oval, long-pointed; sharply doubly serrate; thin and firm; dull green above, lighter beneath, turning scarlet and orange in autumn; petioles short, slender, hairy.

FLOWERS.—May, after the leaves; monoecious; apetalous; the staminate catkins 1-1½ inches long, their scales greenish, boat-shaped, each bearing 3-20 stamens; the pistillate catkins ½-¾ inch long, their scales hairy, greenish, each bearing 2 pistils with long, scarlet styles.

FRUIT.—Ripens in midsummer, but often remains on the tree long after the leaves have fallen; in loose, terminal strobiles; involucre halberd-shaped, inclosing a small, ovate, brownish nut.

WINTER-BUDS.—Terminal bud absent; lateral buds ⅛ inch long, narrow-ovoid, acute, puberulous, brownish.

BARK.—Twigs pale green, hairy, becoming lustrous, dark red the first winter; trunk and large limbs thin, smooth, close, dark bluish gray, often mottled with lighter or darker patches.

WOOD.—Heavy, hard, tough, very strong, close-grained, light brown, with thick, whitish sapwood.

DISTRIBUTION.—Frequent throughout Vermont at the lower altitudes.

HABITAT.—Deep, rich, moist soil along the borders of streams and swamps. Often found in drier situations in the shade of other trees.

NOTES.—The blue beech is a small, bushy tree rarely over twenty feet high. It is not uncommon in moist soil along streams, but does not reach the higher altitudes. It is distinguished in spring by its tiny flowers arranged in loose catkins and in July by the curious leaf-like wings which develop upon the fruit. A glance at its trunk makes its recognition certain at any time of year. It has a close, gray bark resembling that of the beech but with furrows and ridges suggesting the muscles of a strong man's arm. It is the toughest of all our woods.

THE BIRCHES

The birches are distributed widely over the Old and the New Worlds, being most abundant in the higher latitudes. Nine species occur in North America, four of which are found in Vermont. They are all graceful trees with slender flexuous branches and delicate foliage. Both the ovule-bearing and pollen-bearing flowers are found on the same tree, but in separate clusters. The staminate catkins are long and drooping, while the pistillate are shorter and not pendulous until fruited.

The wood of birches is valued chiefly for cabinet making, spools and other small articles.

SUMMER KEY TO THE SPECIES OF BETULA

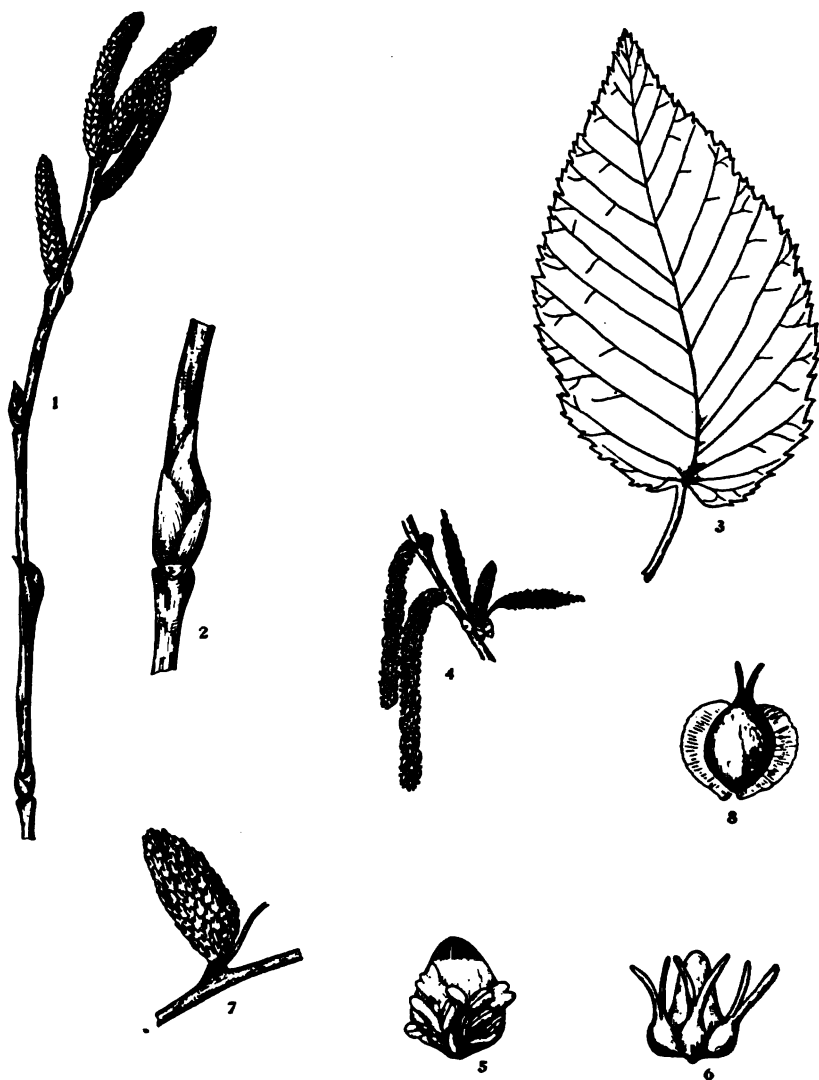
- a.* Bark of trunk chalky-white; twigs without wintergreen taste.
 - b.* Twigs usually warty-glandular; bark of trunk not separating freely into thin, papery layers; inner bark dingy yellow; leaves nearly triangular to rhombic-ovate, long-pointed; small tree, with trunk 6-10 inches in diameter. ***B. populifolia***, p. 103.
 - bb.* Twigs not warty-glandular; bark of trunk separating freely into thin, papery layers, exposing the bright cinnamon-yellow inner bark; leaves ovate, not long-pointed; large tree, with trunk 1-3 feet in diameter ***B. alba papyrifera***, p. 105.
- aa.* Bark of trunk not chalky-white, usually dark colored; twigs with more or less wintergreen taste.
 - b.* Bark dirty yellow, breaking into strips more or less curled at the edges; leaves solitary or in pairs, slightly aromatic; twigs with slight wintergreen taste ***B. lutea***, p. 101.
 - bb.* Bark dark red-brown, cleaving off in thick, irregular plates (resembles bark of black cherry); leaves in pairs, strongly aromatic; twigs with strong wintergreen taste. ***B. lenta***, p. 99.

WINTER KEY TO THE SPECIES OF BETULA

- a.* Bark of trunk chalky-white; twigs without wintergreen taste.
 - b.* Twigs usually warty-glandular; bark of trunk not separating freely into thin, papery layers; inner bark dingy yellow; small tree, with trunk 6-10 inches in diameter. . . ***B. populifolia***, p. 103.
 - bb.* Twigs not warty-glandular; bark of trunk separating into thin, papery layers, exposing the bright cinnamon-yellow inner bark; large tree, with trunk 1-3 feet in diameter,

B. alba papyrifera, p. 105.
- aa.* Bark of trunk not chalky-white, usually dark colored; twigs with more or less wintergreen taste.
 - b.* Bark dirty yellow, breaking into strips more or less curled at the edges; twigs with slight wintergreen taste. . . ***B. lutea***, p. 101.
 - bb.* Bark dark red-brown, cleaving off in thick, irregular plates (resembles bark of black cherry); twigs with strong wintergreen taste ***B. lenta***, p. 99.

Cherry Birch. Sweet Birch. Black Birch



(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{1}{2}$.
4. Flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flower, enlarged.
7. Fruiting branchlet, x $\frac{1}{2}$.
8. Fruit, enlarged.

BETULACEAE**Cherry Birch. Sweet Birch. Black Birch*****Betula lenta* L.**

HABIT.—A medium-sized tree 50-75 feet high, with a trunk diameter of 1-3 feet; slender, wide-spreading, pendulous branches, forming a narrow, rounded, open crown.

LEAVES.—Alternate in pairs, simple, 3-4 inches long and one-half as broad; outline variable, ovate to oblong-ovate; sharply doubly serrate, with slender, incurved teeth; dull, dark green above, light yellow-green beneath; petioles short, stout, hairy, deeply grooved above; aromatic.

FLOWERS.—April-May, before the leaves; monoecious; the staminate catkins 3-4 inches long, slender, pendent, yellowish; the pistillate catkins $\frac{1}{2}$ - $\frac{3}{4}$ inch long, erect or suberect, greenish.

FRUIT.—Ripens in autumn; sessile, glabrous, erect strobiles, 1-1 $\frac{1}{2}$ inches long and half as thick; scales glabrous; nuts slightly broader than their wings.

WINTER-BUDS.—Terminal bud absent; lateral buds about $\frac{1}{4}$ inch long, conical, sharp-pointed, red-brown, divergent.

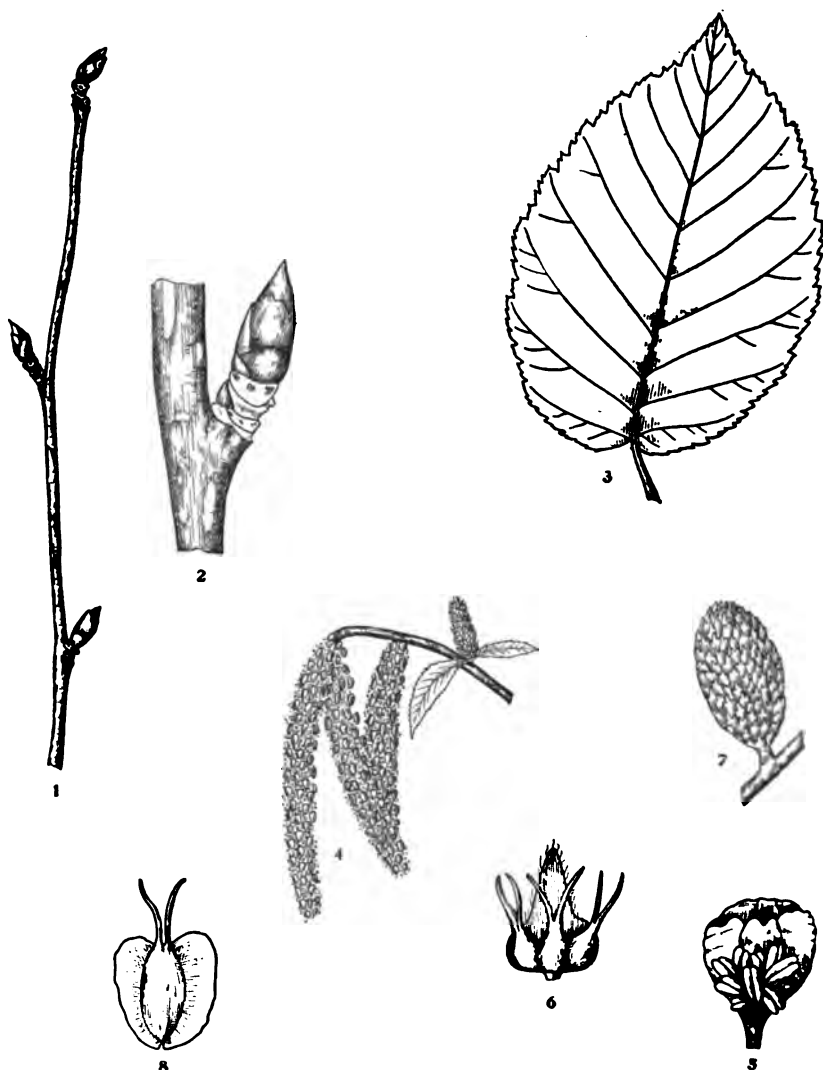
BARK.—Twigs light green, becoming lustrous, red-brown in their first winter; very dark on old trunks, cleaving off in thick, irregular plates. Resembles bark of black cherry. Inner bark aromatic, spicy.

WOOD.—Heavy, very hard and strong, close-grained, dark red-brown, with thin, lighter colored sapwood.

DISTRIBUTION.—Frequent in western Vermont to the foot-hills of the Green mountains and known in the Connecticut valley as far north as Hartford.

HABITAT.—Rich woodlands of the lower altitudes.

NOTES.—The distinctive characters of this tree are well known to many Vermonters, who, as children, have become familiar with the sweet wintergreen flavor of bark and leaves. It is common in western Vermont, but reaches only the foothills of the Green mountains. Its northern limit in the Connecticut valley is in the vicinity of Norwich. Two kinds of catkins are noticeable upon the bare trees in winter; and they open on the first spring days, before most other trees have made a visible response to the sun's rays. The wood is valuable for furniture and fuel.

Yellow Birch. Gray Birch

(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{1}{2}$.
4. Flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flower, enlarged.
7. Fruiting branchlet, x $\frac{1}{2}$.
8. Fruit, x 10.

BETULACEAE**Yellow Birch. Gray Birch*****Betula lutea* Michx. f.**

HABIT.—A tree 60-80 feet high and 2-4 feet in trunk diameter; numerous slender, pendulous branches form a broad, open, rounded crown.

LEAVES.—Alternate, solitary or in pairs, simple, 3-5 inches long and one-half as broad; ovate to oblong-ovate; sharply doubly serrate; dull dark green above, yellow-green beneath; petioles short, slender, grooved, hairy; slightly aromatic.

FLOWERS.—April-May, before the leaves; monoecious; the staminate catkins 3-4 inches long, slender, pendent, purplish yellow; the pistillate catkins sessile or nearly so, erect, almost 1 inch long, greenish.

FRUIT.—Ripens in autumn; sessile or short-stalked, erect, glabrous strobiles, about 1 inch long and half as thick; scales downy on the back and edges; nut about as broad as the wing.

WINTER-BUDS.—Terminal bud absent; lateral buds about $\frac{1}{4}$ inch long, conical, acute, chestnut-brown, more or less appressed; bud-scales more or less pubescent.

BARK.—Twigs, branches and young stems smooth, very lustrous, silvery gray or light orange; becoming silvery yellow-gray as the trunk expands and breaking into strips more or less curled at the edges; old trunks becoming gray or blackish, dull, deeply and irregularly fissured into large, thin plates; somewhat aromatic, slightly bitter. Plate III.

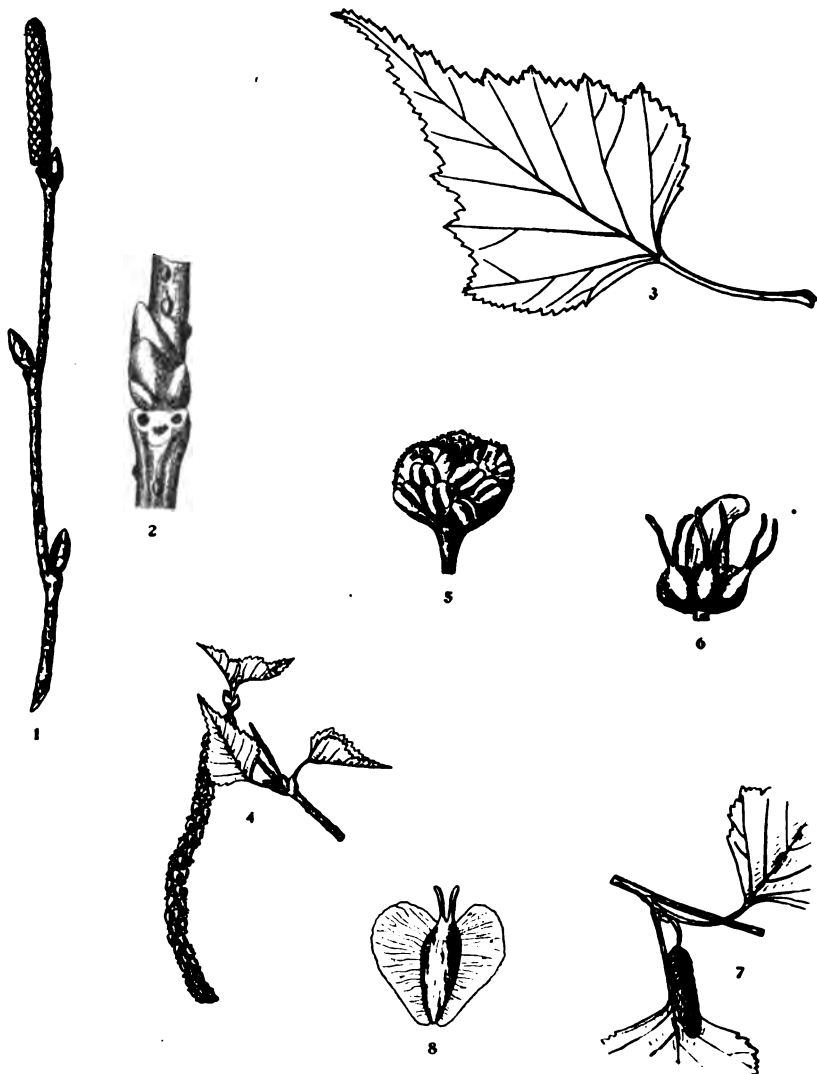
WOOD.—Heavy, very strong and hard, close-grained, light brown tinged with red, with thin, whitish sapwood. Page 227.

DISTRIBUTION.—Frequent throughout Vermont, especially on the mountain slopes up to 1,000 feet altitude.

HABITAT.—Rich, cool soils; mountain slopes; borders of swamps.

NOTES.—The polished silvery yellow bark of the mature tree marks the yellow birch almost as clearly as does the red-brown bark in the case of the preceding species. On the oldest trees in the primeval forest, however, the bark becomes a darker bronze and rough. It is common in nearly all parts of Vermont, but especially in rich, cool soils, and it extends far up the sides of our higher mountains. During the winter the little catkins remain tightly closed, but by May they lengthen into slender, drooping catkins. Yellow birch lumber is valuable for many purposes. It takes a beautiful polish, and is becoming increasingly popular for furniture and for flooring. Because of its graceful form and attractive, yellow bark, it merits more general usage for ornamental planting.

White Birch. Gray Birch. Old Field Birch



1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x 1.
4. Flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flower, enlarged.
7. Fruiting branchlet, x $\frac{1}{2}$.
8. Fruit, enlarged.

BETULACEAE**White Birch. Gray Birch. Old Field Birch*****Betula populifolia* Marsh.**

HABIT.—A small tree 20-30 feet high, with a slender, usually leaning trunk 6-10 inches in diameter; slender, somewhat contorted branches clothe the trunk to the ground, forming a narrow-pyramidal, open, pointed crown; commonly growing in clusters of several trunks.

LEAVES.—Alternate, solitary or in pairs, simple, 2-3 inches long and two-thirds as broad; nearly triangular to rhombic-ovate, long-pointed; coarsely doubly serrate; lustrous, dark green above, paler beneath; petioles long, slender, covered with black glands. Tremulous with the slightest breeze.

FLOWERS.—April-May, with the leaves; monoecious; the staminate catkins usually solitary, 2-4 inches long, slender, pendent, yellowish; the pistillate catkins $\frac{1}{2}$ -1 inch long, erect or suberect, greenish, on peduncles $\frac{1}{2}$ inch long.

FRUIT.—Ripens in autumn; slender-stalked, pubescent, erect or drooping strobiles, about 1 inch long and one-third as thick; scales finely hairy; nuts slightly narrower than their wings.

WINTER-BUDS.—Terminal bud absent; lateral buds $\frac{1}{8}$ - $\frac{1}{4}$ inch long, ovoid, acute, pale brown, divergent.

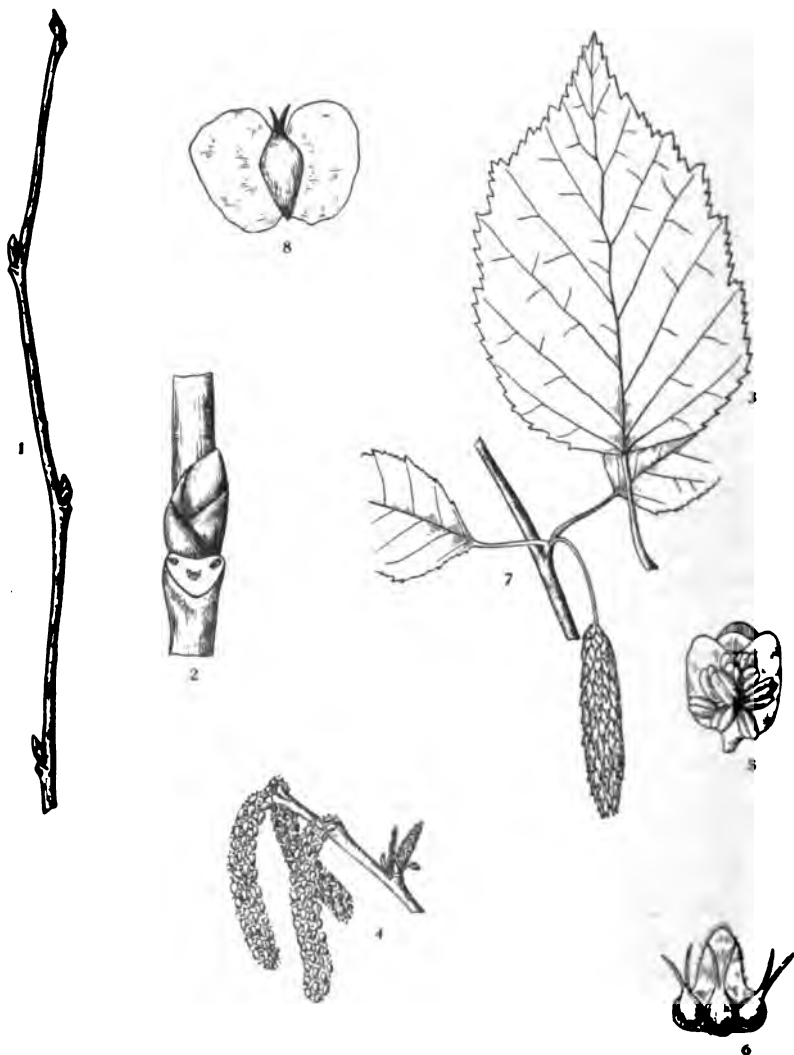
BARK.—Twigs green and warty-glandular, becoming smooth and red-brown; bark of trunk close, not peeling, dull chalky-white on the outer surface, with dark, triangular patches below the insertion of branches, reddish yellow on the inner, becoming nearly black and shallowly fissured at the base of old trunks.

WOOD.—Light, soft, weak, close-grained, light brown, with thick, whitish sapwood.

DISTRIBUTION.—Common in the Champlain valley; frequent in the southern portion of Vermont.

HABITAT.—Poor, sandy soil; old fields; waste lands.

NOTES.—The white birch at best is but a small, short-lived tree, but it grows in such numbers that it is sure to attract attention. It never reaches sufficient size to become a valuable lumber tree, but its light elastic stem always is in demand for spools, shoe-pegs, and barrel-hoops. The white birch with its white trunk and graceful branches and light, delicate foliage is one of our most beautiful trees, but its desirability for transplanting is lessened by its short life and liability to injury from storms.

Paper Birch. Canoe Birch. White Birch

(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x 1.
4. Flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flower, enlarged.
7. Fruiting branchlet, x $\frac{1}{2}$.
8. Fruit, x $3\frac{1}{2}$.

BETULACEAE**Paper Birch. Canoe Birch. White Birch*****Betula alba papyrifera* (Marsh.) Spach. [*Betula papyrifera* Marsh.]**

HABIT.—A tree 50-75 feet high, with a trunk diameter of 1-3 feet, forming in youth a compact, pyramidal crown of many slender branches, becoming in old age a long, branchless trunk with a broad, open crown, composed of a few large limbs ascending at an acute angle, with almost horizontal branches and a slender, flexible spray.

LEAVES.—Alternate, simple, 2-3 inches long, $1\frac{1}{2}$ -2 inches broad; ovate; coarsely, more or less doubly serrate; thick and firm; glabrous, dark green above, lighter beneath, covered with minute black glands; petioles stout, yellow, glandular, glabrous or pubescent.

FLOWERS.—April-May, before the leaves; monoecious; the staminate catkins clustered or in pairs, 3-4 inches long, slender, pendent, brownish; the pistillate catkins about $1\frac{1}{2}$ inches long, slender, erect or spreading, greenish; styles bright red.

FRUIT.—Ripens in autumn; long-stalked, cylindrical, glabrous, drooping strobiles, about $1\frac{1}{2}$ inches long; scales hairy on the margin; nut narrower than its wing.

WINTER-BUDS.—Terminal bud absent; lateral buds $\frac{3}{4}$ inch long, narrow-ovoid, acute, flattish, slightly resinous, usually divergent.

BARK.—Twigs dull red, becoming lustrous, orange-brown; bark of trunk and large limbs cream-white and lustrous on the outer surface, bright orange on the inner, separating freely into thin, papery layers, becoming furrowed and almost black near the ground. Plate III.

WOOD.—Light, hard, strong, tough, very close-grained, light brown tinged with red, with thick, whitish sapwood.

DISTRIBUTION.—Common throughout Vermont.

HABITAT.—Prefers rich, moist hillsides; borders of streams, lakes and swamps; mountain slopes.

NOTES.—The paper birch is often intermingled with the white birch and is confused popularly with it, although careful observation reveals many characteristics by which the two may be distinguished. The paper birch is a larger tree than the white birch and more widely distributed. The two species are similar in the chalky whiteness of the bark, but that of the white birch clings closely so that it cannot be separated in large layers, whereas the peculiar character of the paper birch is the ease with which ample sheets of the beautiful corky layers may be removed.

Beech



(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{1}{2}$.
4. Flowering branchlet, x $\frac{3}{4}$.
5. Staminate flower, enlarged.
6. Pistillate flower, enlarged.
7. Bur, opened, x 1.
8. Nut, x 1.

FAGACEAE**Beech**

Fagus grandifolia Ehrh. [*Fagus atropunicea* (Marsh.) Sudw.]
[*Fagus ferruginea* Ait.] [*Fagus americana* Sweet]

HABIT.—A beautiful tree, rising commonly to a height of 50-75 feet, with a trunk diameter of 2-4 feet; in the forest, tall and slender, with short branches forming a narrow crown, in the open with a short, thick trunk and numerous slender, spreading branches, forming a broad, compact, rounded crown.

LEAVES.—Alternate, simple, 3-5 inches long, one-half as broad; oblong-ovate, acuminate; coarsely serrate, a vein terminating in each tooth; thin; dark blue-green above, light yellow-green and very lustrous beneath; petioles short, hairy.

FLOWERS.—May, with the leaves; monoecious; the staminate in globose heads 1 inch in diameter, on long, slender, hairy peduncles, yellow-green; calyx campanulate, 4-7-lobed, hairy; corolla 0; stamens 8-10; the pistillate on short, hairy peduncles in 2-flowered clusters surrounded by numerous awl-shaped, hairy bracts; calyx urn-shaped, 4-5-lobed; corolla 0; ovary 3-celled; styles 3.

FRUIT.—Ripens in autumn; a prickly bur borne on stout, hairy peduncles, persistent on the branch after the nuts have fallen; nuts usually 3, $\frac{3}{4}$ inch long, sharply tetrahedral, brownish; sweet and edible.

WINTER-BUDS.—Nearly 1 inch long, very slender, cylindrical, gradually taper-pointed, brownish, puberulous.

BARK.—Twigs lustrous, olive-green, finally changing through brown to ashy gray; close, smooth, steel-gray on the trunk, often mottled by darker blotches and bands. Plate IV.

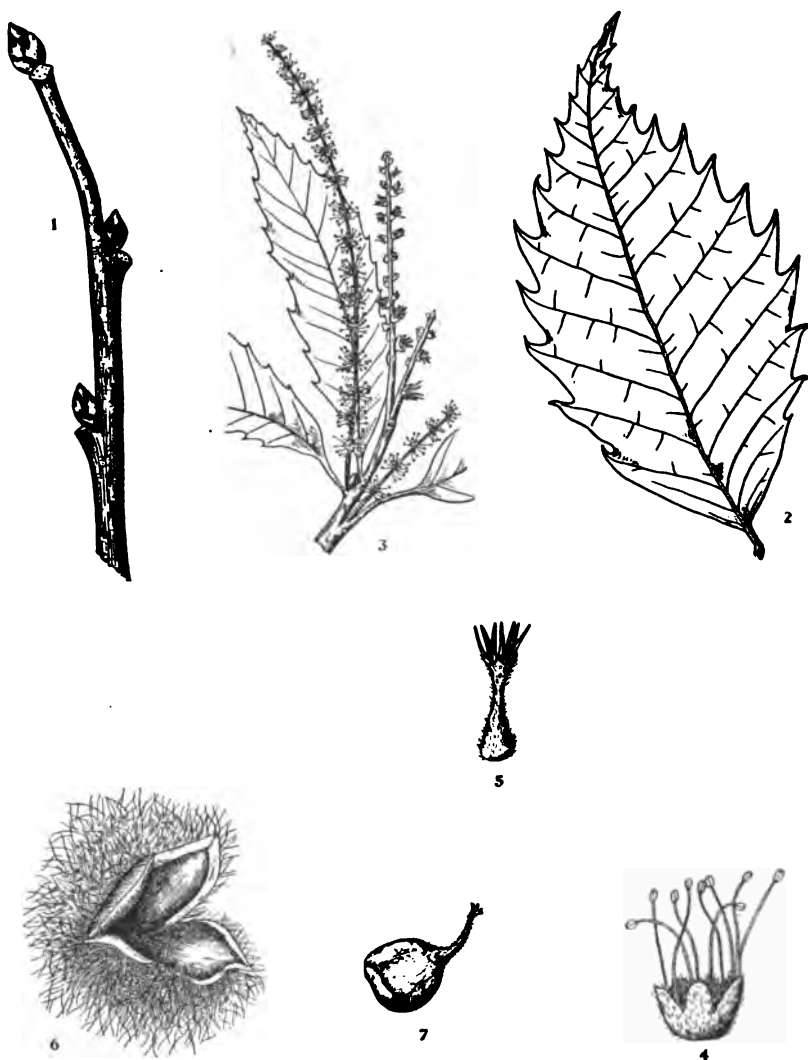
WOOD.—Hard, tough, strong, very close-grained, not durable, difficult to season, light or dark red, with thin, whitish sapwood. Page 227.

DISTRIBUTION.—Abundant throughout Vermont.

HABITAT.—Rich uplands; moist, rocky soil.

NOTES.—The beech, when growing in the forest, with its tall, graceful trunk, its smooth, gray bark and shiny leaves, is a handsome tree. It is not only one of the most common trees in Vermont, but also one of the most widely distributed in eastern North America. The drooping clusters of pollen-bearing flowers and the short, stout ovule-bearing heads open under the newly spreading leaves in early May. The burs open and the nuts fall with the first frosts of autumn.

Chestnut



(Mich. Trees).

1. Winter twig, $\times 1$.
2. Leaf, $\times \frac{1}{2}$.
3. Flowering branchlet, $\times \frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flower, enlarged.
6. Prickly bur, opened, $\times \frac{1}{2}$.
7. Nut, $\times \frac{1}{2}$.

FAGACEAE**Chestnut**

Castanea dentata (Marsh.) Borkh. [*Castanea vesca*, v. *americana* Michx.] [*Castanea sativa*, v. *americana* Sarg.]

HABIT.—A tree 60-80 feet high, forming a short, straight trunk 2-4 feet in diameter, divided not far above the ground into several stout, horizontal limbs and forming a broad, open, rounded crown.

LEAVES.—Alternate, simple, 6-8 inches long, 2-3 inches broad; oblong-lanceolate, long-pointed at the apex; coarsely serrate with stout, incurved, glandular teeth; thin; dull yellow-green above, lighter beneath, glabrous; petioles short, stout, puberulous.

FLOWERS.—July, after the leaves; monoecious; the staminate catkins 6-8 inches long, slender, puberulous, bearing 3-7-flowered cymes of yellow-green flowers; calyx 6-cleft, pubescent; stamens 10-20; the androgynous catkins 2½-5 inches long, puberulous, bearing 2-3 prickly involucre of pistillate flowers near their base; calyx campanulate, 6-lobed; styles 6.

FRUIT.—Ripens in autumn; round, thick, prickly burs, about 2 inches in diameter, containing 1-3 nuts; nuts compressed, brownish, coated with whitish down at the apex; sweet and edible.

WINTER-BUDS.—Terminal bud absent; lateral buds ¼ inch long, ovoid, acute, brownish.

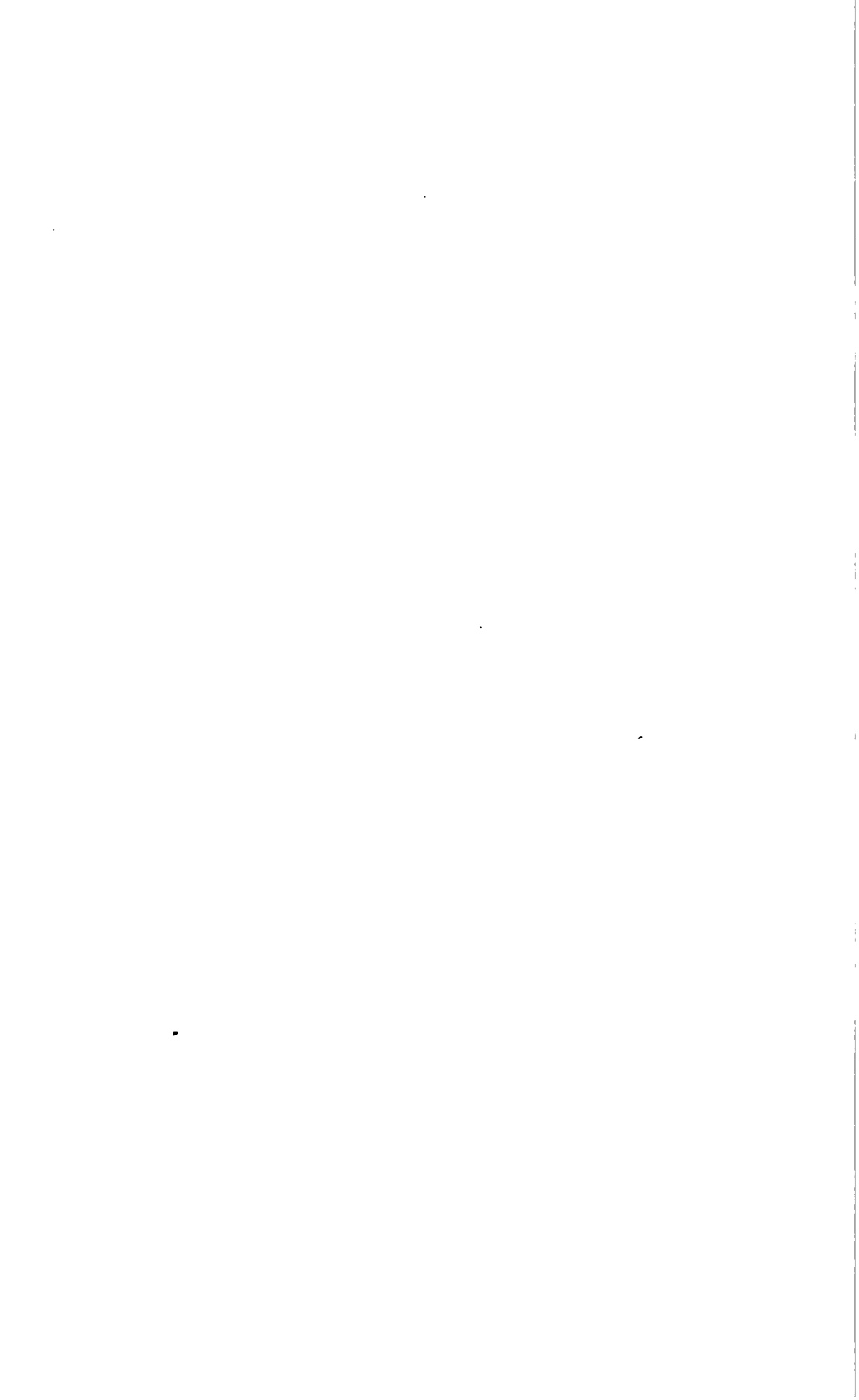
BARK.—Twigs lustrous, yellow-green, becoming olive-green and finally dark brown; old trunks gray-brown, with shallow fissures and broad, flat ridges. Plate IV.

WOOD.—Light, soft, coarse-grained, weak, easily split, very durable in contact with the soil, red-brown, with very thin, lighter colored sapwood.

DISTRIBUTION.—Frequent in the Connecticut valley as far north as Bellows Falls and in southwestern Vermont; occasional as far north as Windsor, West Rutland, Leicester, Burlington, Colchester and Stowe. Planted as far north as Franklin.

HABITAT.—Rocky woods and hillsides.

NOTES.—The chestnut probably will grow in all parts of Vermont. It is a rapid grower and lives to a great age but is subject to a disease which threatens extermination in this country. The leaves are shiny and graceful, from six to eight inches long. When they are nearly grown, long, stiff catkins of fragrant, greenish-yellow flowers appear. These bear the pollen, the ovule-bearing flowers being smaller, enclosed in bur-like scales. The nuts, two or three in a bur, ripen in October.



THE OAKS

The oaks, abundant throughout the northern hemisphere, are remarkable for their massive trunks, their thick, rugged bark and large, strong roots. They are distinguished from all other trees by their cupped fruit, but many who have seen these fruits have not noticed the small, scaly masses of flowers which produce them. The pollen-bearing flowers are found on the same tree, but are arranged in long, slender catkins consisting of a cluster of from three to twelve stamens. Some of the oaks, including the red and black, do not mature their fruit until the second year.

Oak timber is of great commercial value, being used for a variety of purposes. For strength, toughness and durability combined, it is unsurpassed.

The oak genus is a large one. Nine species and two hybrids are included in the last flora of Vermont. They are extremely difficult to tell apart and the late Doctor Pringle remarked that after 25 years of study he did not know the oaks of Vermont. This genus varies greatly and some valuable work could be done in studying its variations.

Only the tree oaks are given in the following keys.

SUMMER KEY TO THE SPECIES OF QUERCUS

- a. Leaves deeply cut or lobed.
 - b. Leaf-lobes acute, bristle-tipped; fruit maturing in the second season.
 - c. Lower surface of leaves more or less pubescent; buds hoary-tomentose; bark of trunk deeply furrowed and scaly; inner bark yellow; nut $\frac{1}{2}$ - $\frac{3}{4}$ inch long, inclosed for about one-half of its length by a deep, turbinate cup. . . . **Q. velutina**, p. 127.
 - cc. Lower surface of leaves glabrous or nearly so; buds glabrous; bark of trunk smoothish or only slightly fissured; inner bark whitish or pinkish; nut about 1 inch long, inclosed only at the base by a shallow, saucer-shaped cup. . . **Q. rubra**, p. 125.
 - bb. Leaf-lobes rounded, not bristle-tipped; fruit maturing in the first season.
 - c. Leaves cut nearly to the midrib by a pair of deep sinuses near the middle of the leaf; branches corky-ridged; nut usually $\frac{3}{4}$ -1 $\frac{1}{2}$ inches long, deeply seated in a large, conspicuously fringed cup **Q. macrocarpa**, p. 117.
 - cc. Leaves not cut by a pair of deep sinuses; branches not corky-ridged; nut about $\frac{3}{4}$ inch long, about one-fourth inclosed by a thin, tomentose, warty cup. **Q. alba**, p. 115.
- aa. Leaves not deeply cut nor lobed.
 - b. Bark on branches breaking into large, papery scales which curl back; acorns on stems 1-4 inches long; tree typical of swamps.
 - Q. bicolor**, p. 119.
 - bb. Bark on branches close, not breaking into large, papery scales; acorns sessile or on stalks less than 1 inch long; trees not typical of swamps.
 - c. Bark of trunk thin, not deeply fissured into inverted V-shaped ridges, flaky, silvery gray or ash colored; leaves coarsely toothed **Q. muhlenbergii**, p. 121.
 - cc. Bark of trunk thick, deeply fissured into inverted V-shaped ridges, not flaky, dark red-brown to nearly black; leaves coarsely crenate **Q. prinus**, p. 123.

WINTER KEY TO THE SPECIES OF QUERCUS

- a.* Terminal buds usually about $\frac{1}{8}$ inch long.
- b.* Twigs thick-tomentose; entire bud pale-pubescent; branches corky-ridged; cup of acorn conspicuously fringed at the rim,
[1]¹ **Q. macrocarpa**, p. 117.
- bb.* Twigs glabrous; buds glabrous, or only slightly or partially pubescent; branches without corky ridges; cup of acorn not conspicuously fringed at the rim.
- c.* Bark on branches breaking into large, papery scales which curl back; buds pilose above the middle; acorns on stems 1-4 inches long [1] **Q. bicolor**, p. 119.
- cc.* Bark on branches not breaking into large, papery scales; buds glabrous; acorns sessile or very short-stalked.
- d.* Buds conical, acute; bud-scales scarious on the margins; nut white-downy at the apex.... [1] **Q. muhlenbergii**, p. 121.
- dd.* Buds broadly ovoid, obtuse; bud-scales not scarious on the margins; nut not white-downy at the apex,
[1] **Q. alba**, p. 115.
- aa.* Terminal buds usually about $\frac{1}{4}$ inch long.
- b.* Buds strictly glabrous throughout; bark of trunk smoothish or only slightly fissured, inner bark not bitter-tasting; nut inclosed only at the base by a shallow, saucer-shaped cup,
[2]² **Q. rubra**, p. 125.
- bb.* Buds more or less pubescent or tomentose; bark of trunk deeply furrowed and roughish, inner bark bitter-tasting; nut inclosed for about one-half of its length by a deep, cup-shaped or turbin-ate cup.
- c.* Buds hoary-tomentose, obtuse at the apex, strongly angled; inner bark of trunk yellow; acorns maturing in autumn of second season; nut $\frac{1}{2}$ - $\frac{3}{4}$ inch long, with bitter kernel,
[2] **Q. velutina**, p. 127.
- cc.* Buds slightly hairy, sharp-pointed, not strongly angled; inner bark of trunk not yellow; acorns maturing in autumn of first season; nut 1-1 $\frac{1}{2}$ inches long, with sweet kernel,
[1] **Q. prinus**, p. 123.

¹ [1] means that the acorns mature in the autumn of the first season, hence mature acorns will not be found on the tree, but on the ground beneath the tree.

² [2] means that the acorns mature in the autumn of the second season, hence immature acorns will be found on the last season's twigs, and mature acorns on the ground beneath the tree.

White Oak



(Mich. Trees).

1. Winter twig, $\times 1\frac{1}{2}$.
2. Leaf, $\times \frac{1}{2}$.
3. Flowering branchlet, $\times \frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flower, enlarged.
6. Fruit, $\times 1$.

FAGACEAE**White Oak*****Quercus alba* L.**

HABIT.—A large tree 50-75 feet high, with a trunk diameter of 2-4 feet; forming a short, thick trunk with stout, horizontal, far-reaching limbs, more or less gnarled and twisted in old age, and a broad, open crown.

LEAVES.—Alternate, simple, 5-9 inches long, about one-half as broad; obovate to oblong; 5-9-lobed, some with broad lobes and shallow sinuses, others with narrow lobes and deep, narrow sinuses, the lobes usually entire; thin and firm; glabrous, bright green above, pale or glaucous beneath; often persistent on the tree through the winter.

FLOWERS.—May, with the leaves; monoecious; the staminate in hairy catkins 2-3 inches long; the pistillate sessile or short-peduncled, reddish, tomentose; calyx campanulate, 6-8-lobed, yellow, hairy; corolla 0; stamens 6-8, with yellow anthers; stigmas red.

FRUIT.—Autumn of first season; sessile or short-stalked acorns; cup with small, brown-tomentose scales, inclosing one-fourth of the nut; nut oblong-ovoid, rounded at the apex, about $\frac{3}{4}$ inch long, light brown; kernel sweet and edible.

WINTER-BUDS.—Terminal bud $\frac{1}{8}$ inch long, broadly ovoid, obtuse; scales smooth, dark red-brown.

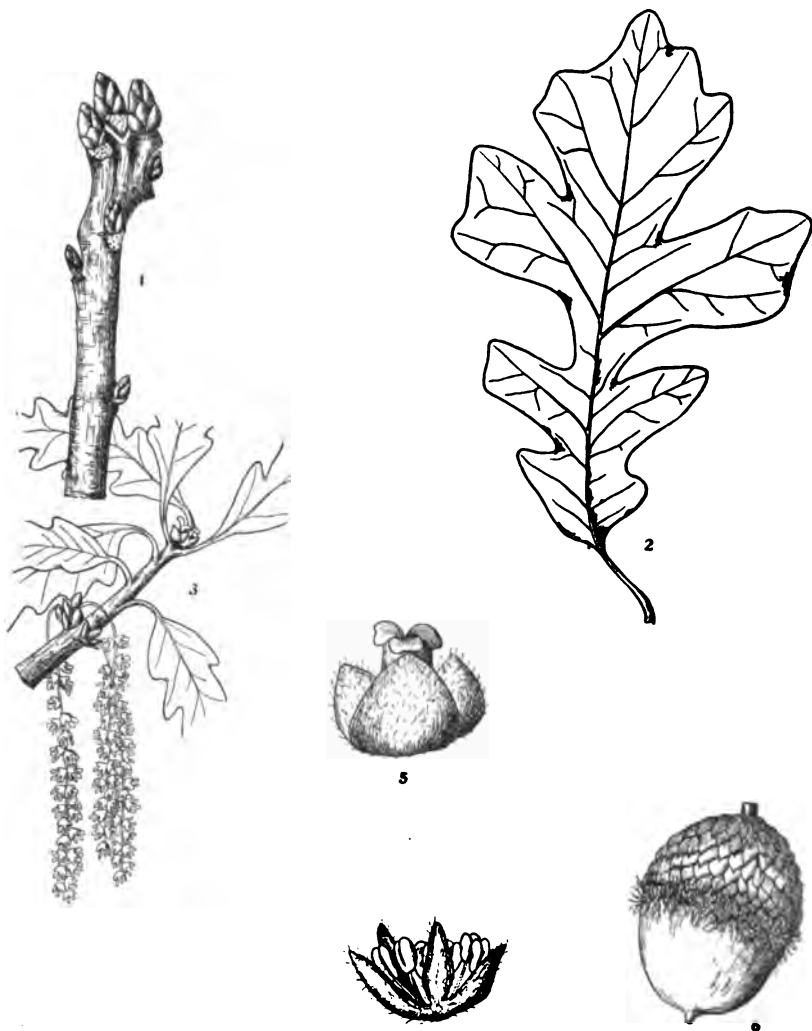
BARK.—Twigs at first bright green, tomentose, later reddish, and finally ashy gray; thick, light gray or whitish on old trunks, shallowly fissured into broad, flat ridges. Plate IV.

WOOD.—Very heavy, strong, hard, tough, close-grained, durable, light brown, with thin, light brown sapwood.

DISTRIBUTION.—Common west of the Green mountains; occurs sparingly in the Connecticut valley as far north as Wells River.

HABITAT.—Grows well in all but very wet soils, in all open exposures; dry woods.

NOTES.—The white oak is the most beautiful as well as the most useful of the oaks found in this part of the United States. Vermont has quite a generous supply of these trees in the Champlain valley. The tough, heavy wood of the white oak needs no recommendation. On account of the beauty of its grain and its capability of taking a high polish, it is used extensively for furniture and for interior finishing. The famous "Charter Oak" of Connecticut was of this species.

Bur Oak. Over-cup Oak. Mossy-cup Oak

(Mich. Trees).

1. Winter twig, x 2.
2. Leaf, x $\frac{1}{4}$.
3. Flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate, enlarged.
6. Fruit, x 1.

FAGACEAE**Bur Oak. Over-cup Oak. Mossy-cup Oak*****Quercus macrocarpa* Michx.**

HABIT.—A medium-sized tree 40-60 feet high, with a trunk 2-4 feet in diameter; great, spreading branches form a broad, rugged crown.

LEAVES.—Alternate, simple, 6-10 inches long and one-half as broad; obovate to oblong, wedge-shaped at the base; crenately lobed, usually cut nearly to the midrib by two opposite sinuses near the middle; thick and firm; dark green and shining above, pale pubescent beneath; petioles short, stout.

FLOWERS.—May, with the leaves; monoecious; the staminate in slender, hairy catkins 4-6 inches long; the pistillate sessile or short-stalked, reddish, tomentose; calyx 4-6-lobed, yellow-green, downy; corolla 0; stamens 4-6, with yellow anthers; stigmas bright red.

FRUIT.—Autumn of first season; sessile or short-stalked acorns; very variable in size and shape; cup typically deep, cup-shaped, tomentose, fringed at the rim, inclosing one-third or all of the nut; nut broad-ovoid, $\frac{1}{2}$ -1 $\frac{1}{2}$ inches long, brownish, pubescent; kernel white, sweet and edible.

WINTER-BUDS.—Terminal bud $\frac{1}{8}$ inch long, broadly ovoid or conical, red-brown, pale-pubescent.

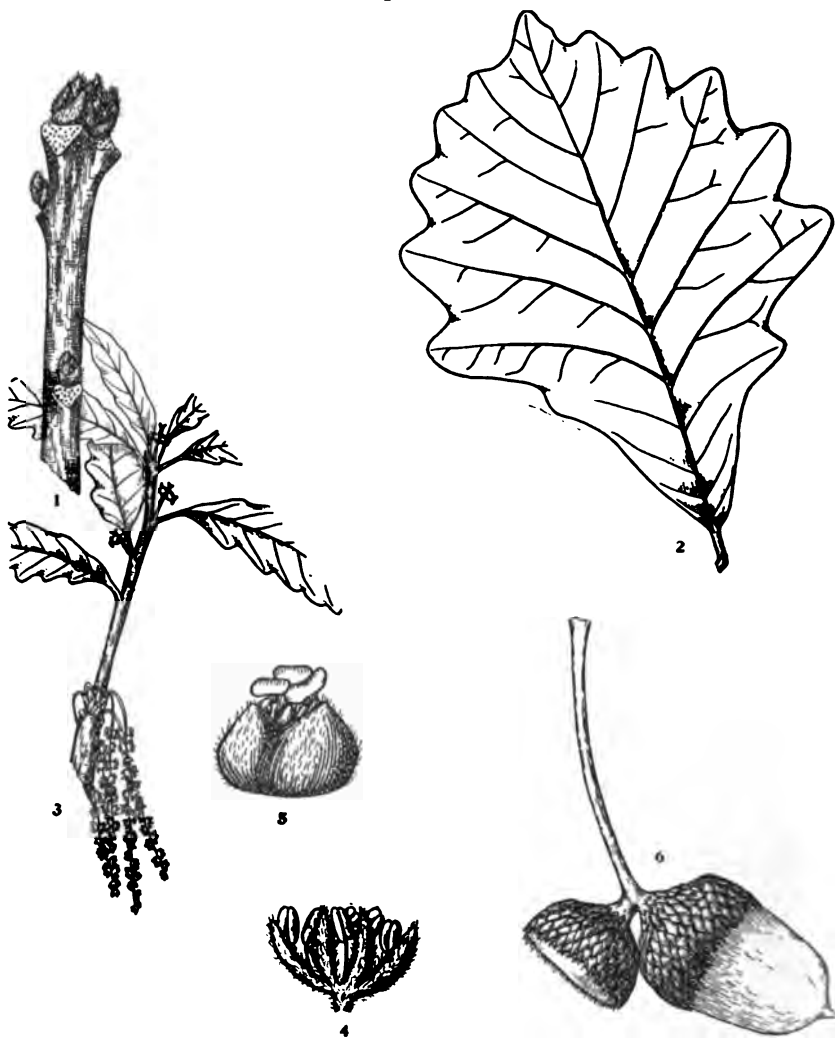
BARK.—Twigs yellow-brown, thick-tomentose, becoming ash-gray or brownish; branches with corky ridges; thick and gray-brown on the trunk, deeply furrowed.

WOOD.—Heavy, hard, strong, tough, close-grained, very durable, brownish, with thin, pale sapwood.

DISTRIBUTION.—Occasional in the Champlain valley, more common in Addison county.

HABITAT.—Prefers rich, moist soil; bottom-lands.

NOTES.—The bur oak is easily recognized by its mossy cups. It is occasionally planted as an ornamental tree, but on account of its large size it is suitable only for parks and large estates. Commercially its wood is not distinguished from the white oak.

Swamp White Oak

(Mich. Trees).

1. Winter twig, x 2.
2. Leaf, x $\frac{1}{2}$.
3. Flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flower, enlarged.
6. Fruit, x 1.

FAGACEAE**Swamp White Oak**

Quercus bicolor Willd. [*Quercus platanoides* (Lam.) Sudw.]

HABIT.—A medium-sized tree 40-60 feet high, with a trunk diameter of 2-3 feet; forming a rather open, rugged crown of tortuous, pendulous branches and short, stiff, bushy spray.

LEAVES.—Alternate, simple, 5-7 inches long, 3-5 inches broad; obovate to oblong-obovate; coarsely sinuate-crenate or shallow-lobed; thick and firm; dark green and shining above, whitish and more or less tomentose beneath; petioles stout, about $\frac{1}{2}$ inch long.

FLOWERS.—May, with the leaves; monoecious; the staminate in hairy catkins 3-4 inches long; the pistillate tomentose, on long, tomentose peduncles, in few-flowered spikes; calyx deeply 5-9-lobed, yellow-green, hairy; corolla 0; stamens 5-8, with yellow anthers; stigmas bright red.

FRUIT.—Autumn of first season; acorns on pubescent stems 1-4 inches long, usually in pairs; cup cup-shaped, with scales somewhat loose (rim often fringed), inclosing one-third of the nut; nut ovoid, light brown, pubescent at the apex, about 1 inch long; kernel white, sweet, edible.

WINTER-BUDS.—Terminal bud $\frac{1}{8}$ inch long, broadly ovoid to globose, obtuse; scales light brown, pilose above the middle.

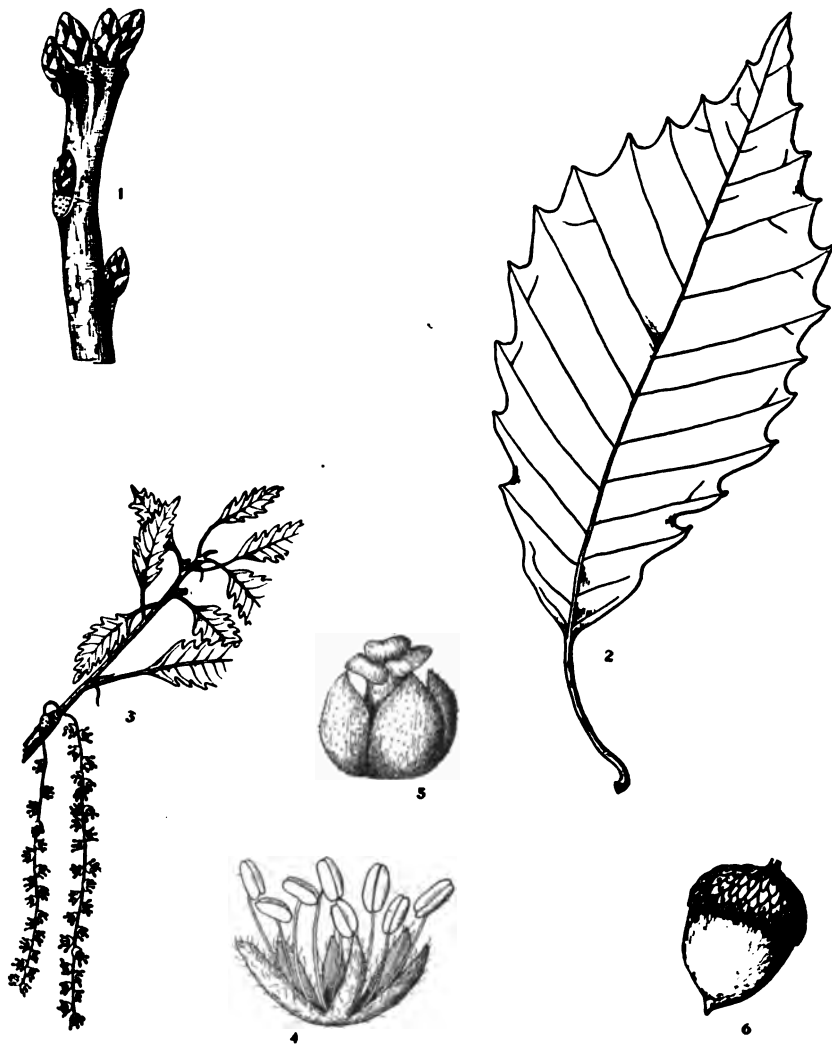
BARK.—Twigs at first lustrous, green, becoming red-brown, finally dark brown and separating into large, papery scales which curl back; thick, gray-brown on the trunk, deeply fissured into broad, flat, scaly ridges. Plate IV.

WOOD.—Heavy, hard, strong, tough, coarse-grained, light brown, with thin, indistinguishable sapwood.

DISTRIBUTION.—Frequent in the Champlain valley, especially about Lake Champlain.

HABITAT.—Prefers moist, rich soil bordering swamps and along streams.

NOTES.—In beauty and variety of grain this tree nearly equals the white oak and its wood is valuable for similar purposes. As its name suggests it grows in low, moist soil. Unfortunately the swamp oak is not found in Vermont except along the intervalles of Lake Champlain and its tributaries. Here it is quite abundant and its majestic size and symmetrical, rounded top make it a conspicuous and beautiful tree. It is more easily identified than many of the oaks because of the scaly bark, the leaves downy on the lower surface and the long, downy stalks of the acorns.

Yellow Oak. Chestnut Oak

(Mich. Trees).

1. Winter twig, $\times 2$.
2. Leaf, $\times \frac{1}{2}$.
3. Flowering branchlet, $\times \frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flower, enlarged.
6. Fruit, $\times 1$.

FAGACEAE**Yellow Oak. Chestnut Oak**

Quercus muhlenbergii Engelm. [*Quercus acuminata* (Michx.) Houba]

HABIT.—A small to medium-sized tree 30-40 feet high, with a trunk diameter of 1-2 feet; erect, somewhat short branches form a narrow, rounded crown.

LEAVES.—Alternate, simple, 4-7 inches long, 1-4 inches broad; oblong-lanceolate to obovate; coarsely toothed; thick and firm; lustrous, yellow-green above, pale-pubescent beneath; petioles slender, about 1 inch long.

FLOWERS.—May, with the leaves; monoecious; the staminate in hairy catkins 3-4 inches long; the pistillate sessile or in short spikes, hoary-tomentose; calyx campanulate, 5-8-lobed, yellow, hairy; corolla 0; stamens 5-8, with yellow anthers; stigmas red.

FRUIT.—Autumn of first season; sessile or short-stalked acorns; cup with small scales, hoary-tomentose, inclosing one-half of the nut; nut ovoid, about $\frac{3}{4}$ inch long, light brown; kernel sweet, sometimes edible.

WINTER-BUDS.—Terminal bud $\frac{1}{8}$ inch long, conical, acute; scales chestnut-brown, scarious on the margin.

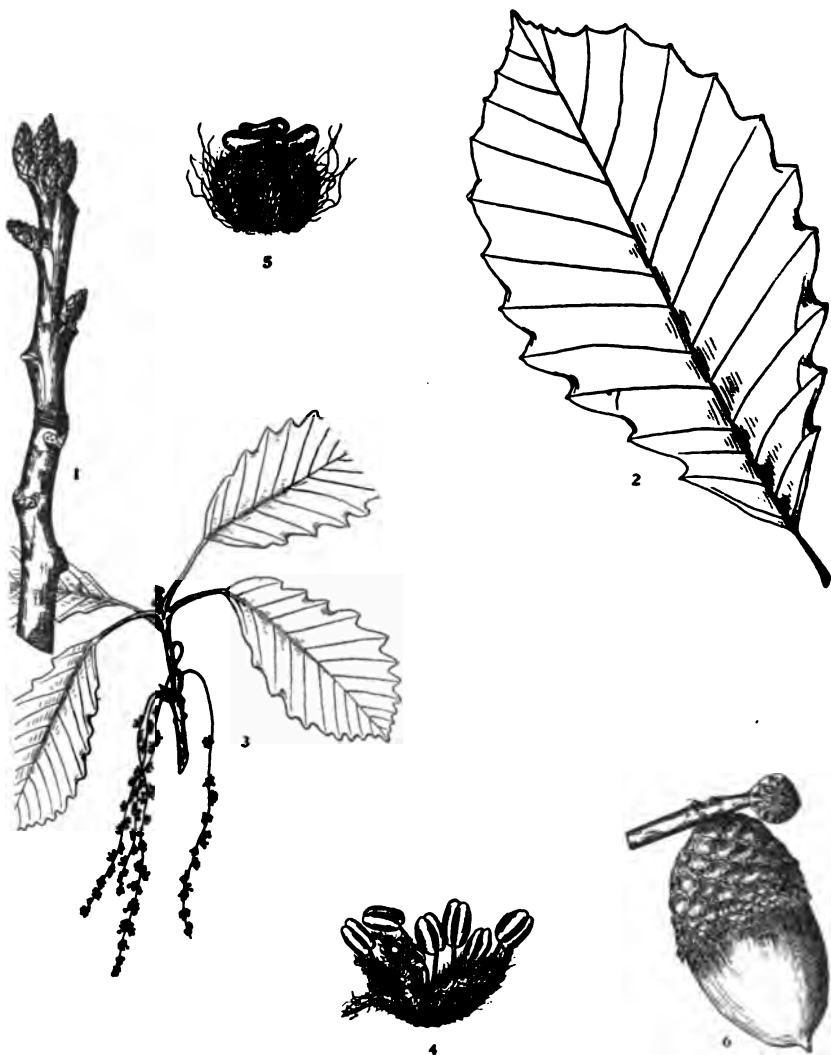
BARK.—Twigs greenish at first, becoming gray-brown, finally gray or brown; thin, silvery gray or ash colored and flaky on the trunk.

WOOD.—Heavy, very hard, strong, close-grained, durable, dark brown, with thin, pale brown sapwood.

DISTRIBUTION.—Rare; reported from Gardiner's island in Lake Champlain, Malletts Head, Ferrisburg and Colchester.

HABITAT.—Dry limestone hillsides; rocky river-banks and lake-shores.

NOTES.—This oak is a very beautiful tree and is well adapted for use in parks and on lawns on account of its handsome foliage.

Chestnut Oak

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{2}$.
3. Flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flower, enlarged.
6. Fruit, x 1.

FAGACEAE**Chestnut Oak*****Quercus prinus* L.**

HABIT.—A medium-sized tree 30-50 feet high, with a trunk diameter of 1-2 feet; usually dividing near the ground into a few large branches and forming a broad, open, rather irregular crown.

LEAVES.—Alternate, simple, 6-8 inches long and one-third to one-half as broad; lanceolate to obovate; coarsely crenate; thick and firm, almost leathery; glabrous, dark green above, paler and finely pubescent beneath; petioles $\frac{1}{2}$ -1 inch long.

FLOWERS.—May, with the leaves; monoecious; the staminate in hairy catkins 2-2½ inches long; the pistillate in short spikes on stout, pubescent peduncles; calyx deeply 7-9-lobed, pale yellow, pilose; corolla 0; stamens 7-9, with yellow anthers; stigmas dark red.

FRUIT.—Autumn of first season; short-stalked acorns; cup thin, deep, turbinate, inclosing one-half or less of the nut; scales small, thin-tipped, with thickened bases, hoary-pubescent; nut ovoid to oblong-ovoid, 1-1½ inches long, light brown; kernel sweet, but insipid.

WINTER-BUDS.—Terminal bud $\frac{1}{4}$ - $\frac{3}{8}$ inch long, ovoid, sharp-pointed; scales light brown, slightly hairy toward the apex and on the margin.

BARK.—Twigs greenish, becoming orange and brown, with somewhat bitter taste; thick, dark red-brown to nearly black on old trunks, deeply fissured into thick, roughish ridges (a section through one of the ridges would resemble an inverted letter V).

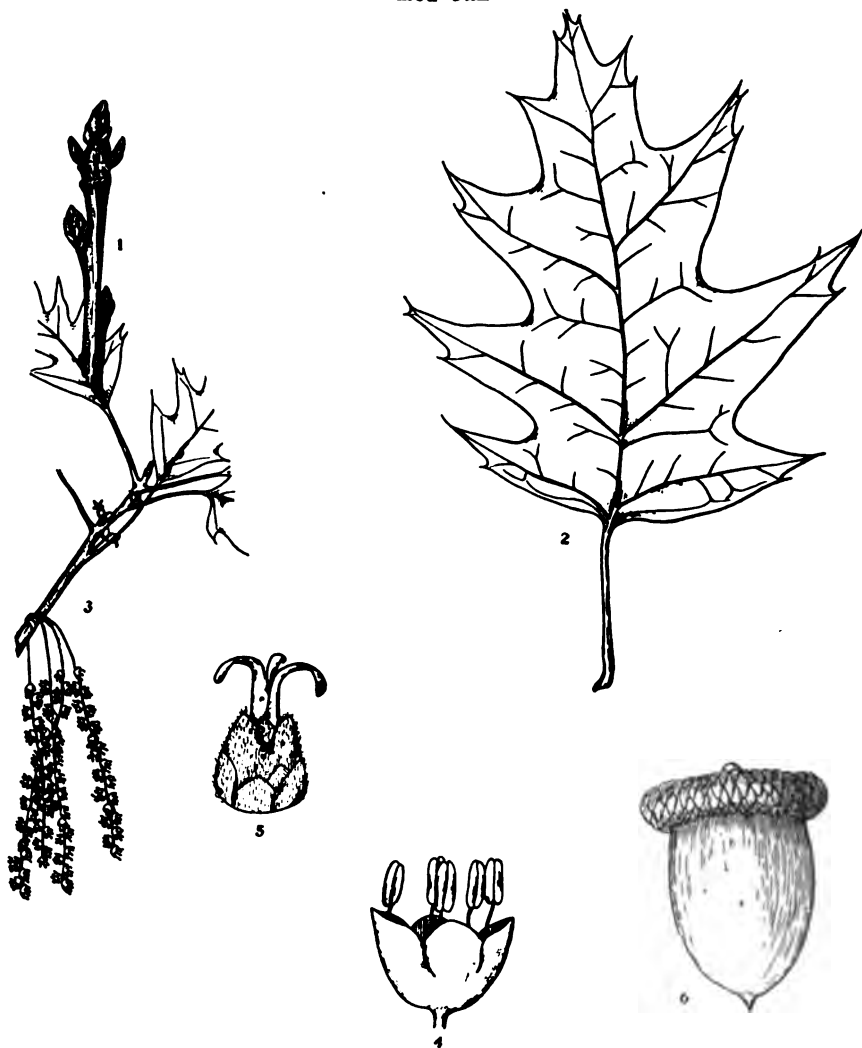
WOOD.—Heavy, hard, strong, tough, close-grained, dark brown, with thin, lighter colored sapwood.

DISTRIBUTION.—Frequent throughout the western part of Vermont from Charlotte to Pownal; abundant on Snake mountain at an altitude of 1,300 feet and on the western slopes of the Green mountains, especially in Addison county.

HABITAT.—Dry, rocky hillsides.

NOTES.—The popular name of this oak is suggested by the marked resemblance of its leaves to those of the chestnut. It is one of the common oaks from Massachusetts and New York southward, forming a large tree on rocky hillsides, often associated with the chestnut. The line of its northern distribution passes through the Champlain valley. It occurs probably also in the southeastern part of Vermont. The acorns are large, one inch or more in length. The wood is hard and tough and is used frequently for railroad ties.

Red Oak



(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{2}$.
3. Flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flower, enlarged.
6. Fruit, x 1.

FAGACEAE**Red Oak*****Quercus rubra* L.**

HABIT.—A large tree 70-80 feet high, with a trunk diameter of 2-4 feet; forming a broad, rounded crown of a few large, wide-spreading branches and slender branchlets.

LEAVES.—Alternate, simple, 5-9 inches long, 4-6 inches broad; oval to obovate; 5-11-lobed with coarse-toothed, bristle-tipped lobes tapering from broad bases and wide, oblique, rounded sinuses; thin and firm; dull dark green above, paler beneath; petioles stout, 1-2 inches long.

FLOWERS.—May, when the leaves are half grown; monoecious; the staminate in hairy catkins 4-5 inches long; the pistillate on short, glabrous peduncles; calyx 4-5-lobed, greenish; corolla 0; stamens 4-5, with yellow anthers; stigmas long, spreading, bright green.

FRUIT.—Autumn of second season; sessile or short-stalked acorns; cup shallow, saucer-shaped, inclosing only the base of the nut; scales closely appressed, more or less glossy, puberulous, bright red-brown; nut oblong-ovoid with a broad base, about 1 inch long, red-brown; kernel white, very bitter.

WINTER-BUDS.—Terminal bud $\frac{1}{4}$ inch long, ovoid, acute, light brown, smooth.

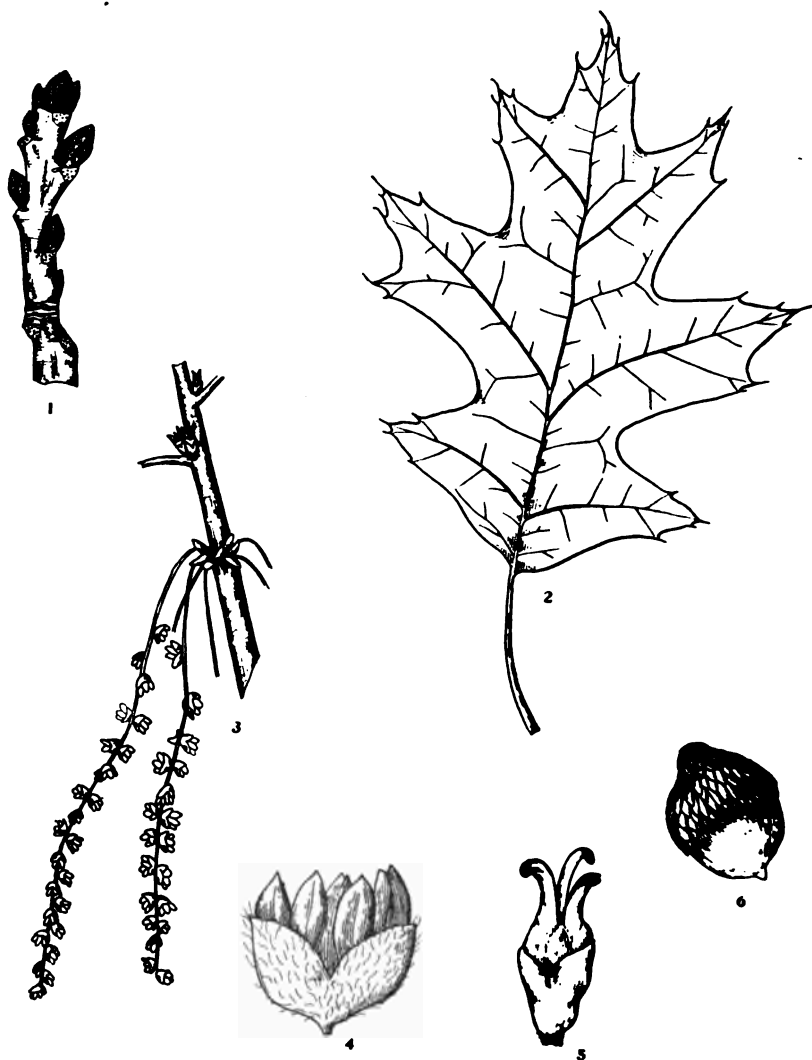
BARK.—Twigs lustrous, green, becoming reddish, finally dark brown; young trunks smooth, gray-brown; old trunks darker, shallowly fissured into thin, firm, broad ridges; inner bark light red, not bitter. Plate V.

WOOD.—Heavy, hard, strong, coarse-grained, light red-brown, with thin, darker colored sapwood. Page 230.

DISTRIBUTION.—Common throughout Vermont at altitudes below 1,000 feet.

HABITAT.—Grows well in all well-drained soils; rich and poor soil.

NOTES.—The red oak is the most northern of all the oaks, ranging from Nova Scotia to Tennessee. It is distributed generally through the Champlain and lower Connecticut valleys where it is the most common oak. It is less common in the northern part of the Connecticut valley. The flowers appear in May but the sessile, shallow-cupped acorns do not ripen until the second autumn. The wood is lighter in weight and more brittle than that of the white oak but when quartered shows a beautiful grain and is used for furniture. It is valued also for bridge posts where there is to be exposure to water. The wood dries out slowly and is inferior as fuel.

Quercifron. Yellow-barked Oak. Black Oak

(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{2}$.
3. Flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flower, enlarged.
6. Fruit, x 1.

FAGACEAE**Quercitron. Yellow-barked Oak. Black Oak*****Quercus velutina* Lam.**

HABIT.—A medium-sized tree 50-60 feet high and 1-3 feet in trunk diameter; slender branches and stout branchlets form a wide-spreading, rounded crown.

LEAVES.—Alternate, simple, 5-10 inches long, 3-8 inches broad; ovate to oblong; usually 7-lobed, some with shallow sinuses and broad, rounded, mucronate lobes, others with wide, rounded sinuses extending half-way to the midrib or farther and narrow-oblong or triangular, bristle-tipped lobes, the lobes more or less coarse-toothed, each tooth bristle-tipped; thick and leathery; dark green and shining above, pale and more or less pubescent beneath; petioles stout, yellow, 3-6 inches long.

FLOWERS.—May, when the leaves are half grown; monoecious; the staminate in pubescent catkins 4-6 inches long; the pistillate reddish, on short, tomentose peduncles; calyx acutely 3-4-lobed, reddish, hairy; corolla 0; stamens usually 4-5, with acute, yellow anthers; stigmas 3, divergent, red.

FRUIT.—Autumn of second season; sessile or short-stalked acorns; cup cup-shaped or turbinate, inclosing about one-half of the nut; scales thin, light brown, hoary; nut ovoid, $\frac{1}{2}$ - $\frac{3}{4}$ inch long, red-brown, often pubescent; kernel yellow, bitter.

WINTER-BUDS.—Terminal bud $\frac{1}{4}$ inch long, ovoid to conical, obtuse, strongly angled, hoary-tomentose.

BARK.—Twigs at first scurfy-pubescent, later glabrous, red-brown, finally mottled gray; thick and nearly black on old trunks, deeply furrowed and scaly; inner bark thick, yellow, very bitter. Plate V.

WOOD.—Heavy, hard, strong, coarse-grained, bright red-brown, with thin, paler sapwood.

DISTRIBUTION.—Frequent in western Vermont and in the Connecticut valley as far north as Bellows Falls.

HABITAT.—Dry, light soil; poor soils.

NOTES.—The quercitron or yellow-barked oak is a southern species which reaches its northern limit in Vermont. It is not uncommon in light, dry soils in the Champlain valley and it occurs also in the southern part of the Connecticut valley. The two common and apparently incompatible names, yellow oak and black oak, arise from the diverse colors of the inner bark and the outer bark. The former, which is used in tanning, is yellow, while the later is very dark. The leaves are rather large, dark, shiny green with yellowish petioles.

THE ELMS

We are fortunate in having in Vermont all of the elms of the eastern United States except one small southern species. The tiny greenish flowers have no petals, but gracefully fringe the bare trees with their long slender stamens in early spring before the appearance of the leaves. The fruits are supplied with a disk-like membranous wing. The leaves of all the elms have a peculiar oblique base, full and rounded upon one side, sharply wedge-shaped on the other.

Introduced species.—The English elm occasionally has been planted as a shade tree, although for such purposes it is less stately than our common white elm. Two European varieties have been more used for ornamental plantings, though each of them is curious rather than ornamental. These are the corky variety of the English elm, and the Camperdown or weeping elm, which is a variety of the Scotch elm. The young branches of the former are covered with conspicuous corky outgrowths, similar to those of the native cork elm, but more strongly developed. The American cork elm is distinguished from the English elm by its more downy bud-scales and by the production of flowers in elongated clusters (racemes), whereas those of the English elm are in close clusters. Other differences will be detected readily by those having occasion to compare the two trees. The weeping elm usually is reverse-grafted on an upright stock, leading to a peculiar umbrella-like development.

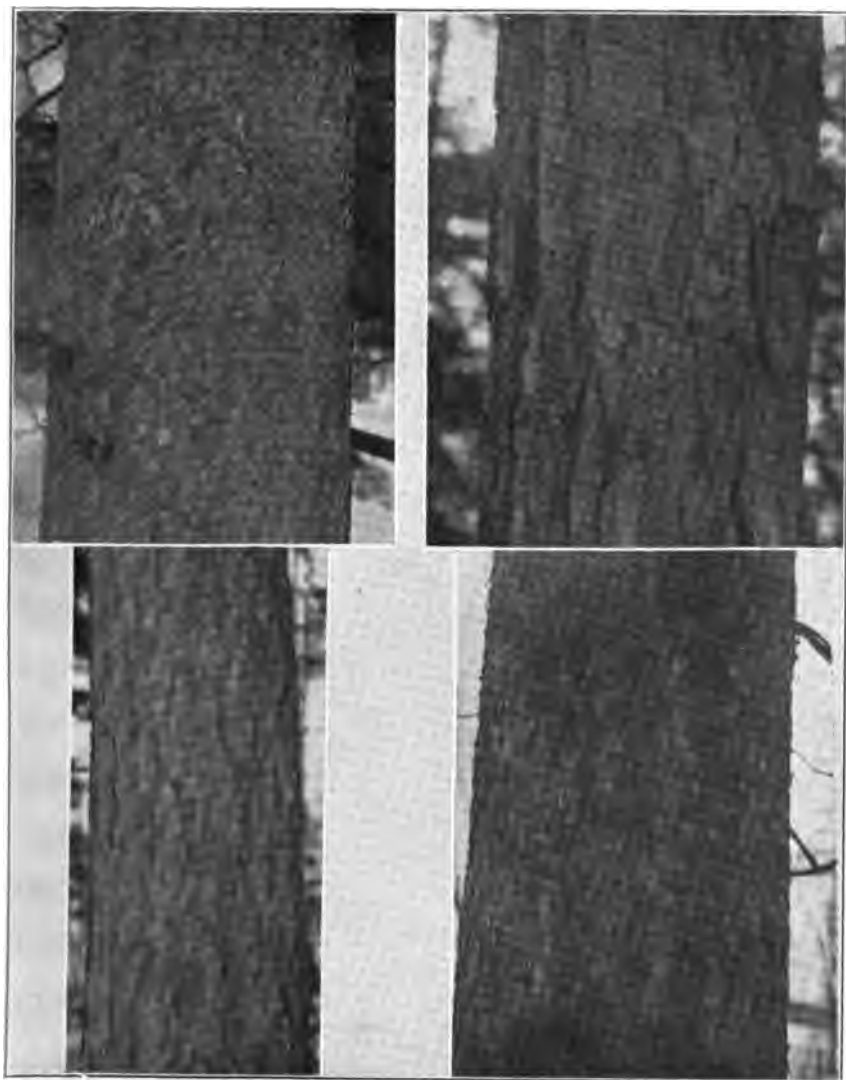


PLATE I.

White Pine

Red Pine

Pitch Pine

Tamarack

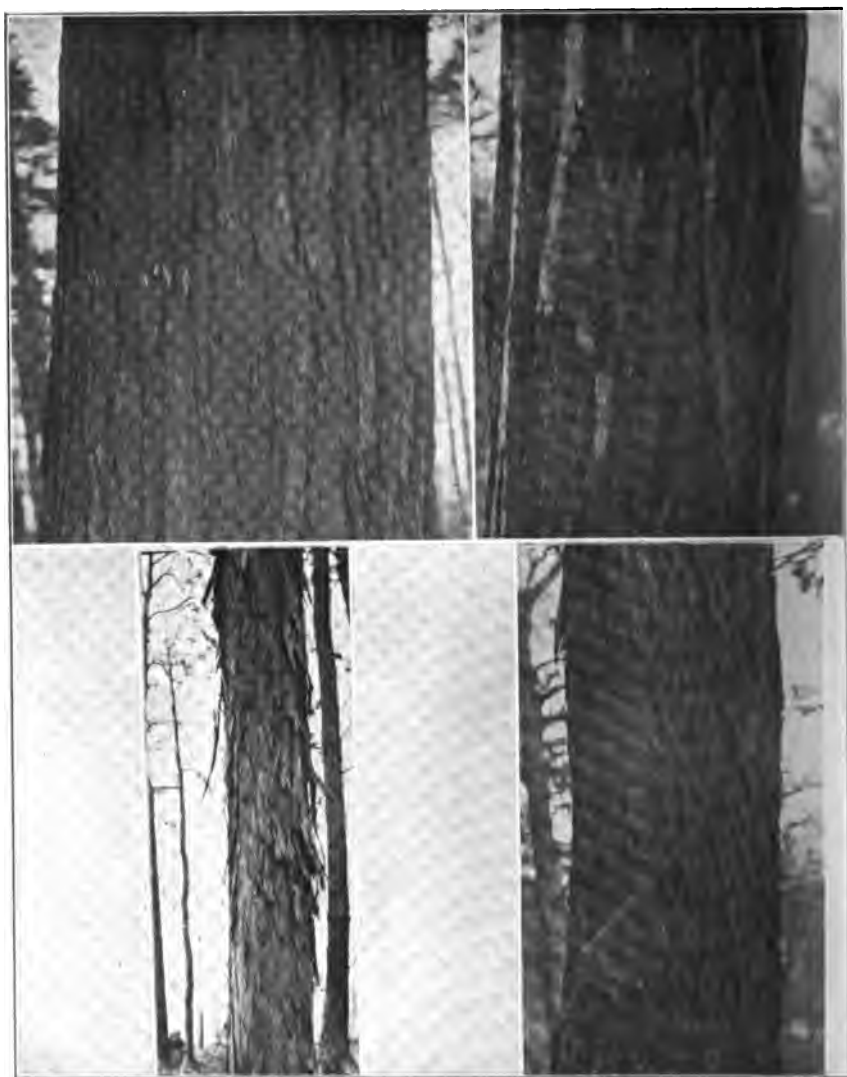


PLATE II.

Hemlock
Shellbark Hickory

Butternut
Pignut

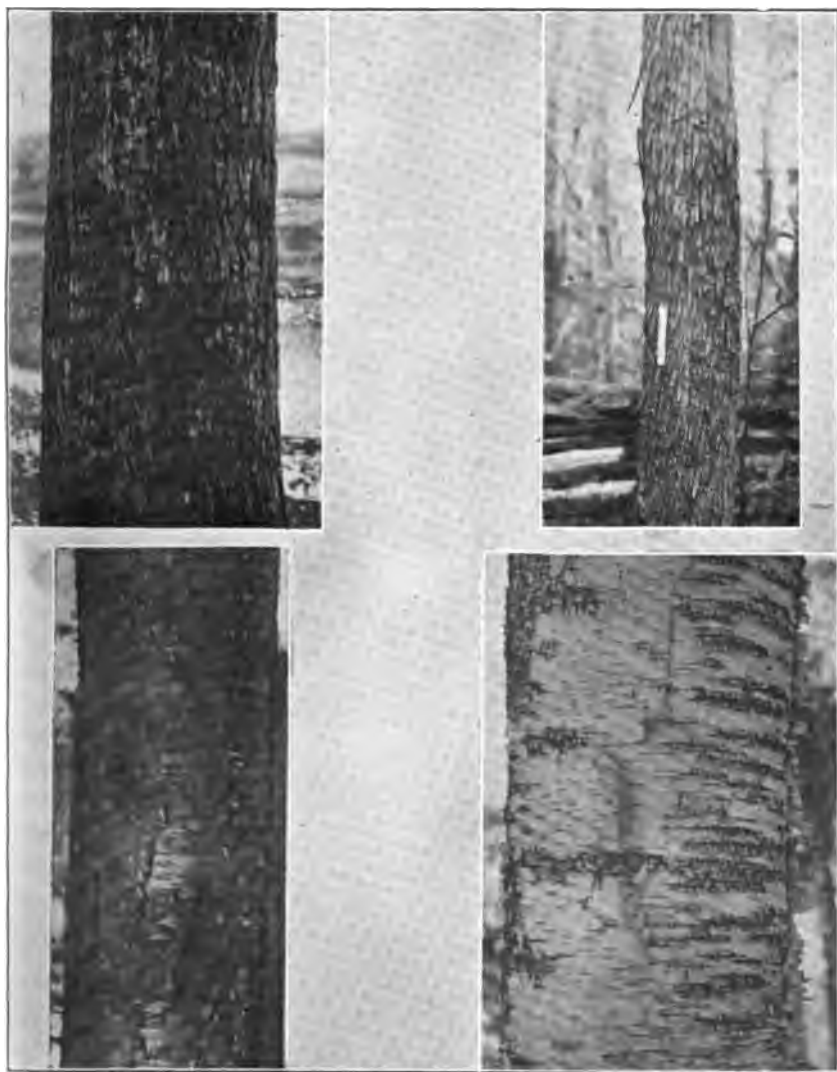


PLATE III.

Bitternut

Yellow Birch

Hornbeam

White Birch

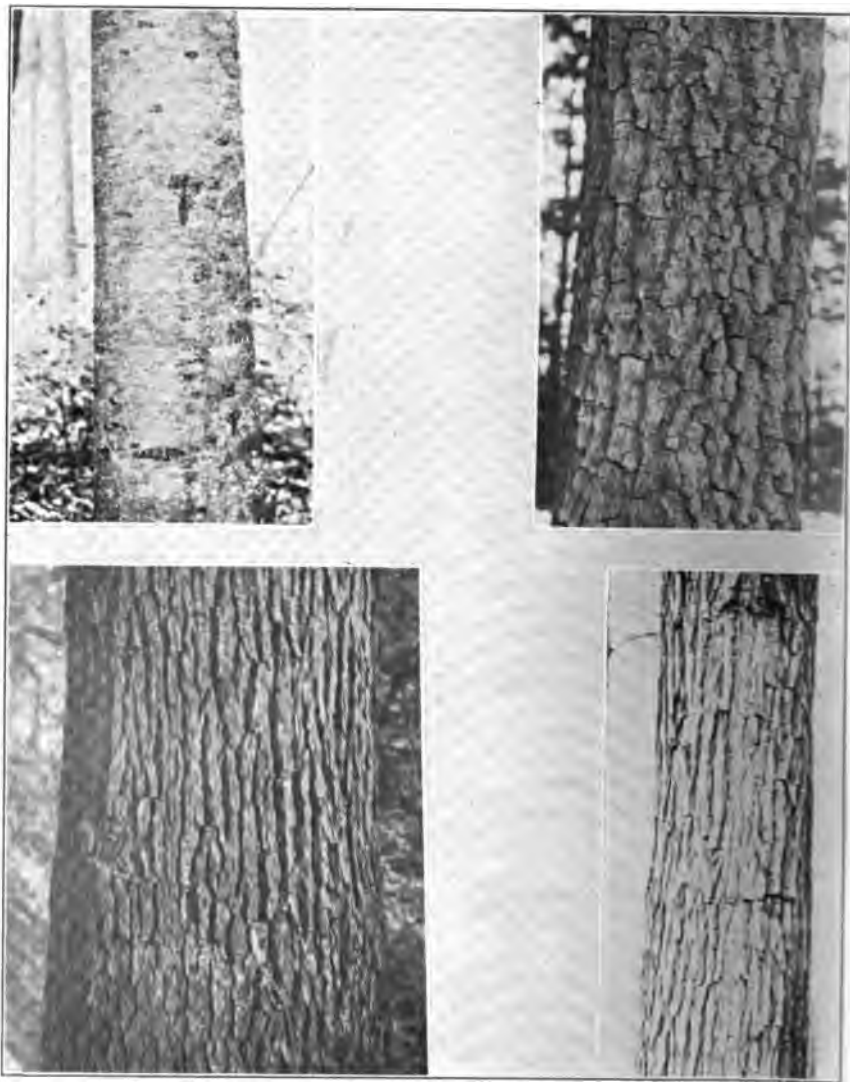


PLATE IV.

Beech

White Oak

Chestnut

Swamp White Oak

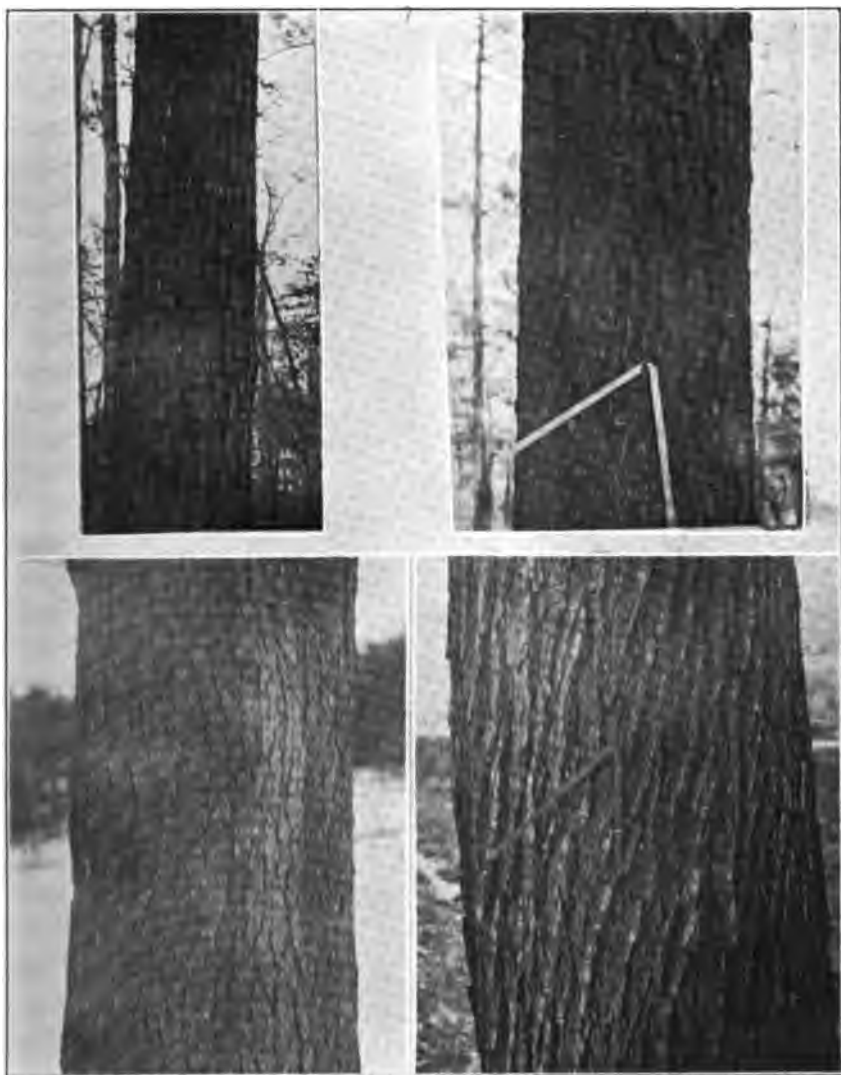


PLATE V.

Red Oak
Slippery Elm

Black Oak
American Elm

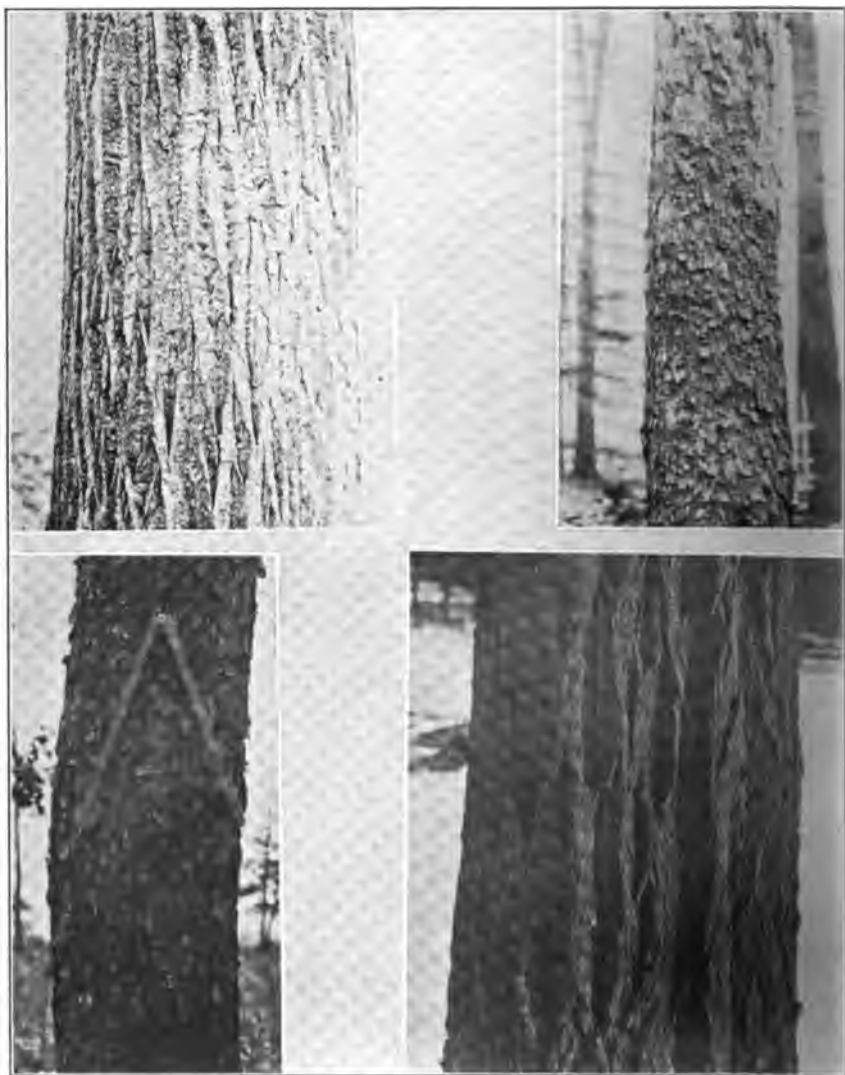


PLATE VI.

Tulip Poplar

Black Cherry

Sycamore

Black Locust

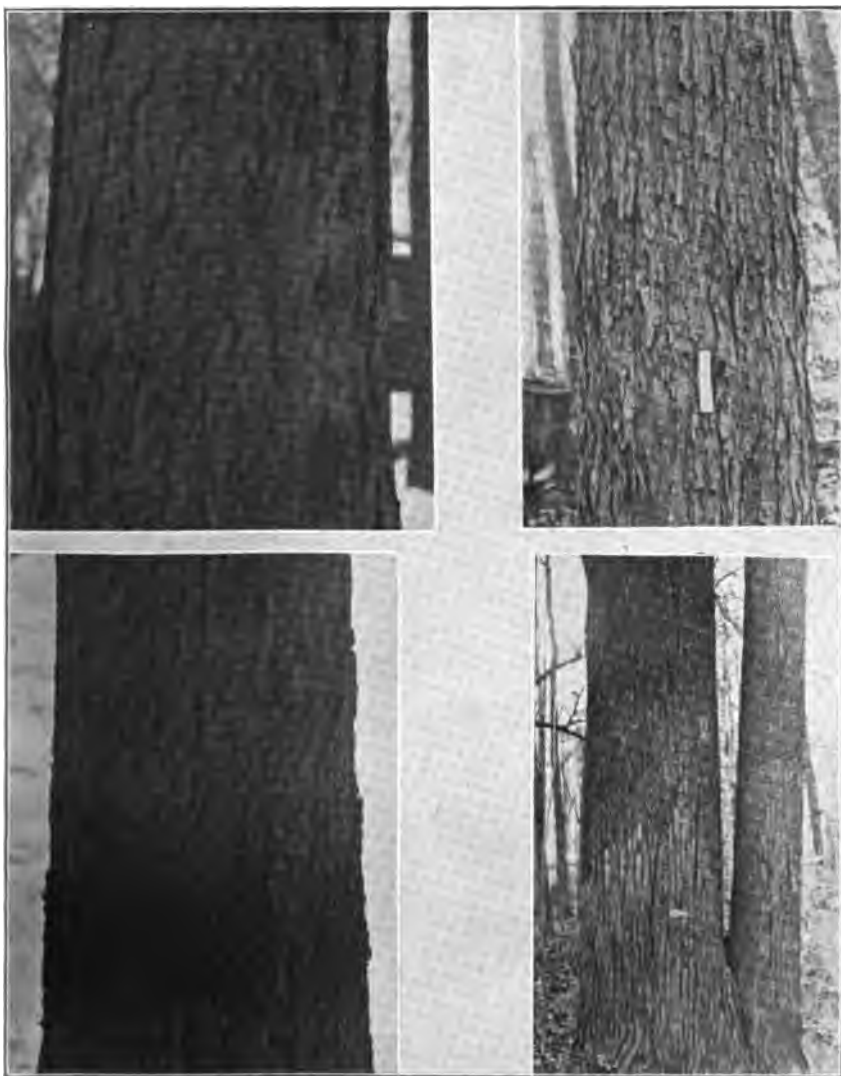


PLATE VII.

Sugar Maple

Red Maple

Silver Maple

Basswood

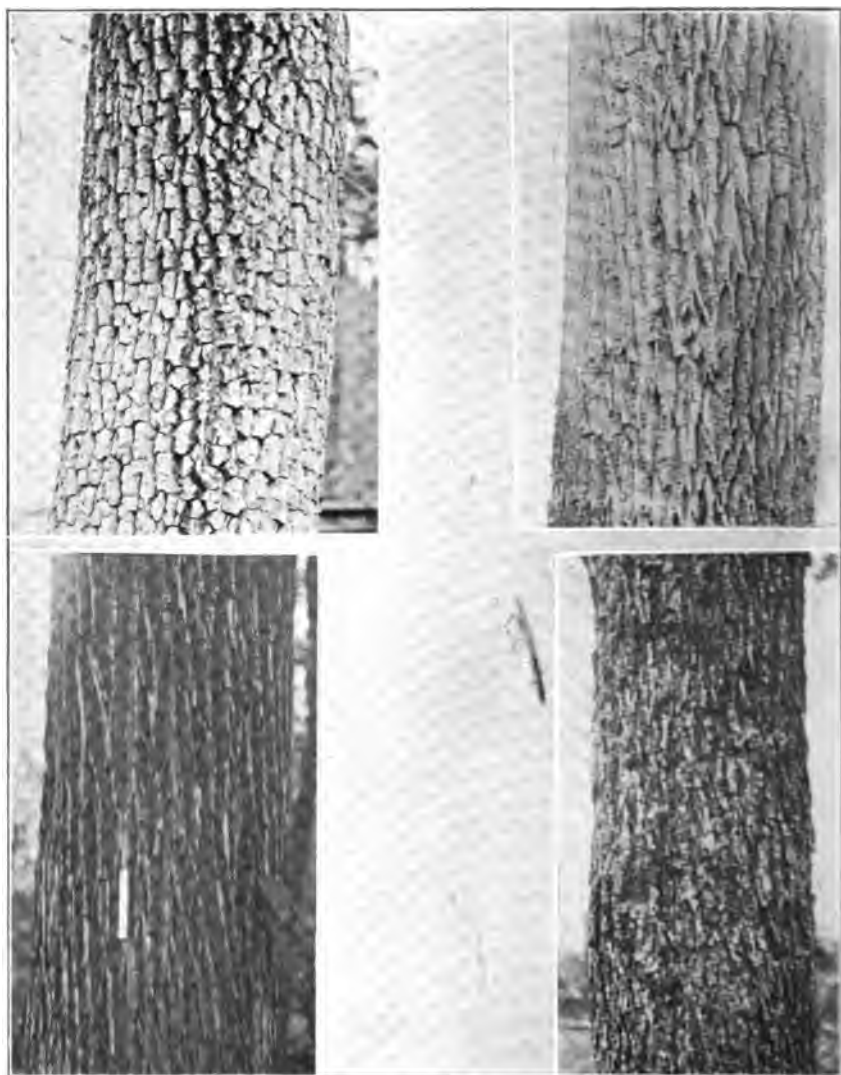


PLATE VIII.

Black Gum

Red Ash

White Ash

Black Ash

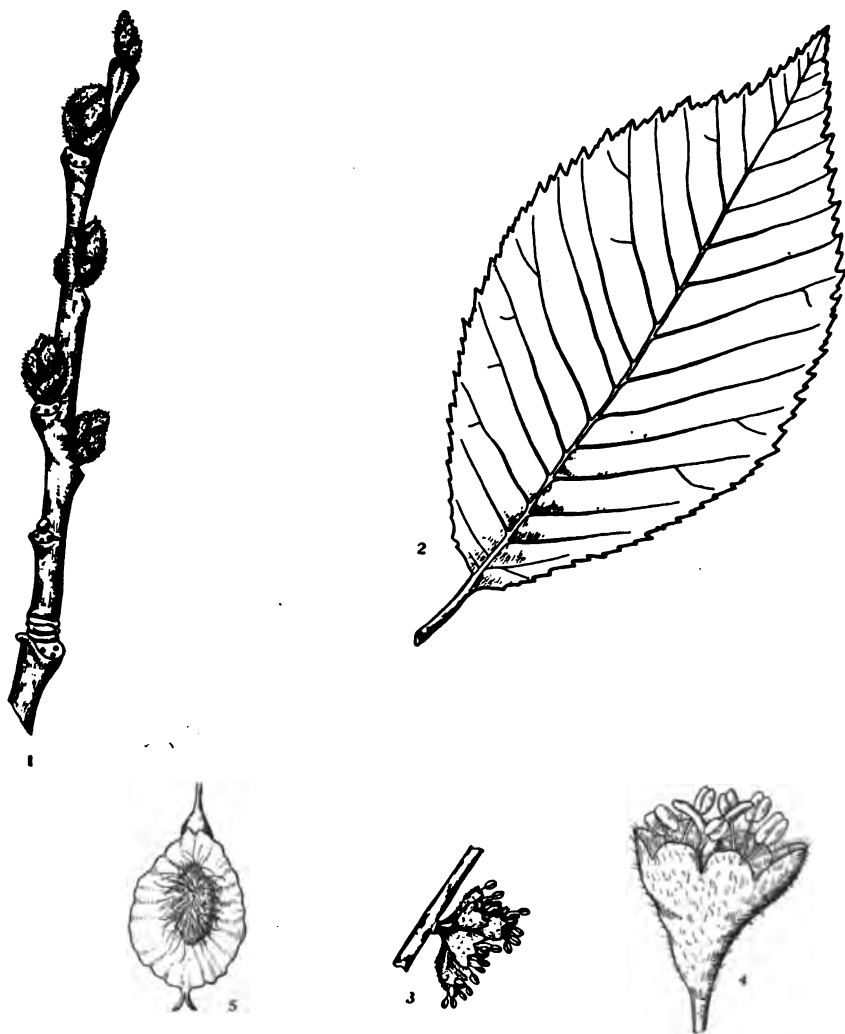
SUMMER KEY TO THE SPECIES OF ULMUS

- a.* Leaves essentially smooth on both sides; branches often with corky, wing-like ridges; lowermost branches usually short and strongly drooping; main trunk usually continuous into the crown without dividing, giving to the tree a narrow-oblong outline,
U. racemosa, p. 135.
- aa.* Leaves usually rough on one or on both sides; branches without corky ridges; lowermost branches not short, not strongly drooping; main trunk usually dividing into several large limbs, giving to the tree a more or less vase-shaped outline.
 - b.* Leaves usually rough above, but smooth beneath, with petioles glabrous; bark of trunk gray, deeply fissured into broad, scaly ridges; inner bark not mucilaginous....**U. americana**, p. 133.
 - bb.* Leaves usually rough both sides, with petioles hairy; bark of trunk dark red-brown, shallowly fissured into large, loose plates; inner bark mucilaginous**U. fulva**, p. 131.

WINTER KEY TO THE SPECIES OF ULMUS

- a.* Buds conspicuously rusty-tomentose; twigs more or less pubescent; inner bark very mucilaginous when chewed....**U. fulva**, p. 131.
- aa.* Buds not conspicuously rusty-tomentose; twigs glabrous; inner bark not mucilaginous.
 - b.* Bundle-scars usually 3; buds $\frac{1}{8}$ inch long, glabrous; twigs without corky ridges; outline of tree vase-shaped,
U. americana, p. 133.
 - bb.* Bundle-scars usually 4-6 in a curved line; buds $\frac{1}{4}$ inch long, somewhat pilose; twigs often with corky ridges; outline of tree narrow-oblong**U. racemosa**, p. 135.

Slippery Elm. Red Elm



(Mich. Trees).

1. Winter twig, x 2.
2. Leaf, x 1.
3. Flowering branchlet, x 1.
4. Perfect flower, enlarged.
5. Fruit, x 1.

URTICACEAE.

Slippery Elm. Red Elm

Ulmus fulva Michx. [*Ulmus pubescens* Walt.]

HABIT.—A medium-sized tree 40-60 feet high, with a short trunk 1-2 feet in diameter; spreading branches form a broad, open, flat-topped crown.

LEAVES.—Alternate, simple, 4-7 inches long, about one-half as broad; ovate-oblong; coarsely doubly serrate; thick and firm; dark green and rough above, paler and somewhat rough beneath; petioles short, stout, hairy.

FLOWERS.—April, before the leaves; mostly perfect; borne on short pedicels in crowded fascicles; calyx campanulate, 5-9-lobed, green, hairy; corolla 0; stamens 5-9, with dark red anthers; stigmas 2, reddish purple.

FRUIT.—May; semi-orbicular, 1-seeded samaras, short-stalked in dense clusters; seed cavity brown-tomentose; wings smooth, nearly $\frac{3}{4}$ inch long.

WINTER-BUDS.—Terminal bud absent; lateral buds ovoid, obtuse, dark brown, rusty-tomentose, $\frac{1}{4}$ inch long.

BARK.—Twigs at first bright green and pubescent, becoming light to dark brown or grayish; thick on old trunks, dark red-brown, shallowly fissured into large, loose plates; inner bark mucilaginous. Plate V.

WOOD.—Heavy, hard, strong, very close-grained, durable, easy to split while green, dark red-brown, with thin, lighter colored sapwood.

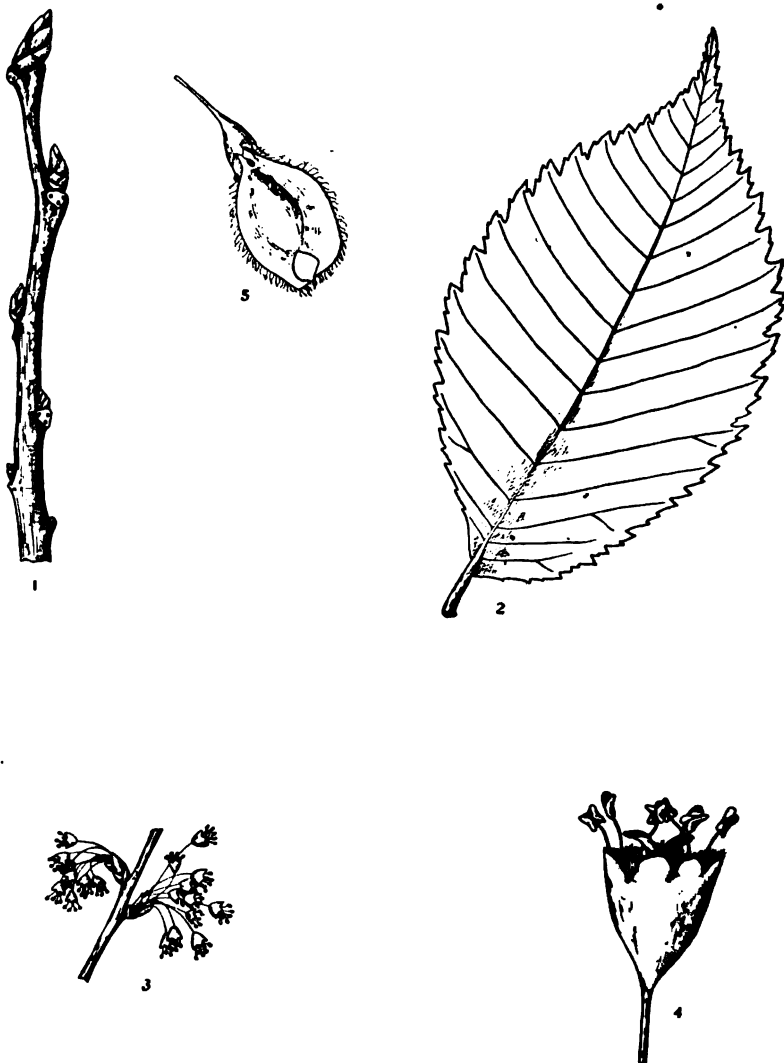
DISTRIBUTION.—Occasional throughout Vermont.

HABITAT.—Rich, rocky woods.

NOTES.—The slippery elm is not uncommon in Vermont. The scattering trees of this species, however, usually are passed unnoticed because it resembles the American elm so closely that it is not easy to distinguish the two by general appearance. The stringy mucilaginous bark of the slippery elm always is a sure means of recognition.

Other means of distinguishing it are found in its circular fruits, which appear in May; these have smooth margins, whereas those of both the other species are fringed with delicate hairs. The leaves are large, rough above and soft-downy beneath. But the surest and simplest test is the "slippery" bark. This has well-known medicinal properties which give it a recognized value in the drug trade. The slippery elm is usually found on rocky ridges and hillsides.

American Elm. White Elm



(Mich. Trees).

1. Winter twig, $\times 2$.
2. Leaf, $\times \frac{1}{2}$.
3. Flowering branchlet, $\times \frac{1}{2}$.
4. Flower, enlarged.
5. Fruit, $\times 2$.

URTICACEAE

American Elm. White Elm

Ulmus americana L.

HABIT.—A tree 75-100 feet high, with a trunk diameter of 2-6 feet; commonly dividing 20-30 feet above the ground into a few large branches which rise upward and outward to form a vase-shaped outline.

LEAVES.—Alternate, simple, 4-6 inches long, one-half as broad; obovate-oblong to oval; coarsely doubly serrate; thick and firm; dark green and rough above, pale and pubescent or glabrous beneath; petioles short and stout.

FLOWERS.—April, before the leaves; mostly perfect; small, brown to red; borne on slender pedicels in loose fascicles; calyx campanulate, 5-9-lobed; corolla 0; stamens 4-9, with bright red anthers; ovary 2-celled; styles 2, green.

FRUIT.—May; ovate, 1-seeded samaras, smooth both sides, hairy on the margin, $\frac{1}{2}$ inch long, long-stemmed in crowded clusters.

WINTER-BUDS.—Terminal bud absent; lateral buds ovoid, acute, flattened, glabrous, brown, $\frac{1}{8}$ inch long.

BARK.—Twigs at first light green and downy, becoming glabrous, red-brown, finally ash-gray; on old trunks thick, ash-gray, deeply fissured into broad, scaly ridges. Plate V.

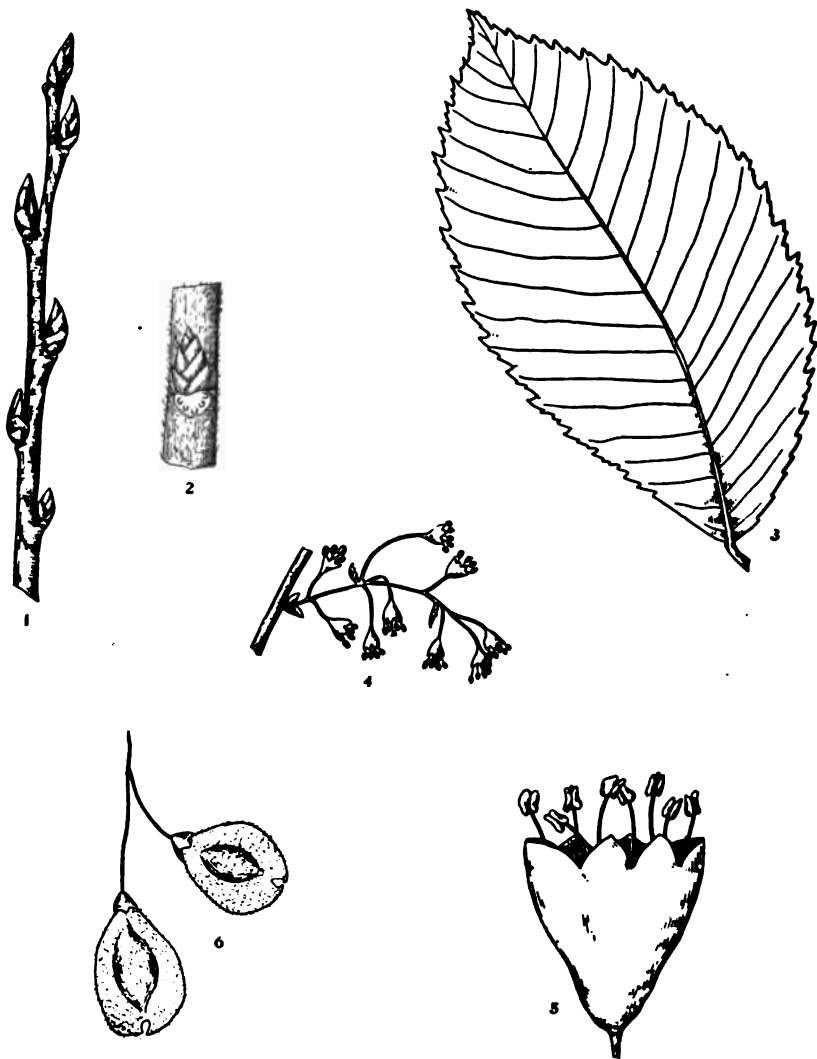
WOOD.—Heavy, hard, strong, tough, difficult to split, coarse-grained, light brown, with thick, lighter colored sapwood. Page 225.

DISTRIBUTION.—Common throughout Vermont.

HABITAT.—Prefers deep, rich, moist loam; bottom-lands; stream-banks.

NOTES.—Of all the native trees none has done more than the white elm to beautify the streets of our cities and villages or to grace our country hillsides and meadows. The spreading vase-shaped head is its typical form, but perfect trees are found only where there has been a free development of the branches from the sapling age. Even when developing freely, however, the trees vary markedly in form. Some may be found which are very strict and upright others which are straggling and strongly weeping. The bark characters also vary much in different trees. Numerous clusters of slender, drooping flowers open before the leaves in early May, giving the tree a delicate feathery appearance. The seeds mature and fall before the leaves are grown fully. The wood is very tough and fibrous, making it useful for ox yokes, wagon bolsters, hubs of wheels and similar purposes where there is special cross-strain.

Cork Elm



(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x 1.
4. Flowering branchlet, x 1.
5. Flower, enlarged.
6. Fruit, x 1.

URTICACEAE

Cork Elm

Ulmus racemosa Thomas [Ulmus Thomasi Sarg.]

HABIT.—A large tree reaching a height of 50-75 feet and a trunk diameter of 2-3 feet; strongly drooping lateral and lower branches form a narrow, oblong crown.

LEAVES.—Alternate, simple, 3-6 inches long, one-half as broad; obovate to oblong-oval, more or less dishd; coarsely doubly serrate; thick and firm; lustrous, dark green above, pale-pubescent beneath; petioles pubescent, $\frac{1}{4}$ inch long.

FLOWERS.—April-May, before the leaves; mostly perfect; greenish; borne on slender, drooping pedicels in loose racemes; calyx campanulate, 7-8-lobed; corolla 0; stamens 7-8, with purple anthers; ovary hairy, 2-styled.

FRUIT.—May-June; ovate, 1-seeded samaras, pubescent all over, $\frac{1}{2}$ inch long.

WINTER-BUDS.—Terminal bud absent; lateral buds ovoid, acute, brown, pilose, $\frac{1}{4}$ inch long.

BARK.—Twigs at first light brown and pubescent, becoming lustrous, red-brown, finally gray-brown with corky, wing-like ridges; thick and grayish on the trunk, with wide fissures separating broad, flat, scaly ridges.

WOOD.—Heavy, very strong and tough, close-grained, light red-brown, with thick, lighter colored sapwood.

DISTRIBUTION.—Western Vermont, west of the Green mountains, becoming relatively more abundant in the Champlain valley; rare.

HABITAT.—River-banks and limestone soils.

NOTES.—The cork elm is a more valuable timber tree but it is found only in the limestone soils of western Vermont, and there but rarely. Its peculiarity is a growth of corky ridges which sometimes project for half an inch or more from all sides of the younger branches. The leaves resemble those of the white elm but are more conspicuously downy upon the under side along the midribs. The bud-scales are also downy and the young branchlets somewhat so, whereas those of the white elm are smooth. The flowers are borne in open branching clusters, or racemes, and this characteristic gives the Latin name to the species. The fruit matures when the leaves are half grown.

Red Mulberry



(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x 1.
4. Spike of staminate flowers, x 1.
5. Staminate flower, enlarged.
6. Spike of pistillate flowers, x 1.
7. Pistillate flower, enlarged.
8. Fruit, x 1.

URTICACEAE**Red Mulberry*****Morus rubra* L.**

HABIT.—A small tree 15-20 feet high, with a short trunk 10-15 inches in diameter; forming a dense, rough-topped crown of stout, spreading branches and more or less zigzag, slender branchlets.

LEAVES.—Alternate, simple, 3-5 inches long, nearly as broad; outline variable, ovate to semiorbicular, often 3-5-lobed; coarsely serrate; thin; dark blue-green and smooth or rough above, pale and more or less downy beneath; petioles 1-2 inches long, smooth, exuding a milky juice when cut.

FLOWERS.—May, with the leaves; monoecious or dioecious; the staminate in dense spikes 1-2 inches long, on short, hairy peduncles; the pistillate in dense spikes about 1 inch long, on short, hairy peduncles; calyx 4-lobed, hairy; corolla 0; stamens 4, with green anthers; stigmas 2, spreading.

FRUIT.—July; 1 inch long; consisting of drupes about $\frac{1}{32}$ inch long, each inclosed in a thickened, fleshy calyx; berry-like; bright red at first, finally blackish; sweet, juicy, edible.

WINTER-BUDS.—Terminal bud absent; lateral buds ovoid, abruptly pointed, $\frac{1}{4}$ inch long, lustrous, light brown.

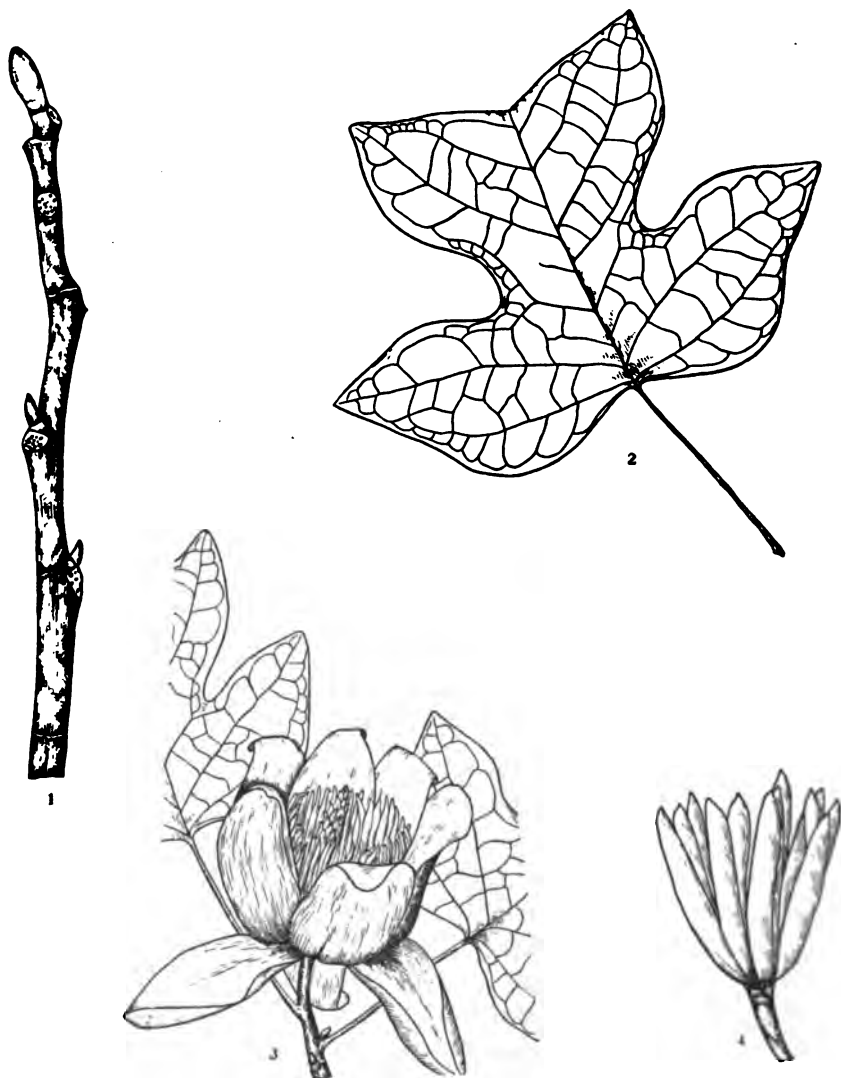
BARK.—Twigs greenish and more or less downy, becoming smooth and brownish; trunk dark brown tinged with red and more or less furrowed.

WOOD.—Light, soft, weak, rather tough, coarse-grained, very durable, pale orange, with thick, lighter colored sapwood.

DISTRIBUTION.—Rare; reported from Pownal and North Pownal in the Hoosic valley.

HABITAT.—Prefers rich soil in river-bottoms; rich woods.

NOTES.—The name mulberry is applied very commonly in Vermont to one of the wild raspberries, which has a conspicuous rose-like blossom followed by a reddish raspberry fruit. This shrub should be called the purple flowering raspberry since the true mulberries are trees. Two species of mulberry occur in Vermont; of these, the red is native, and the white is introduced, and occasionally is an escape. The fruit of both is edible, somewhat resembling that of the blackberry in size and appearance. The leaves are heart-shaped or ovate, often cut into curiously irregular lobes so that no two leaves on a branch will be exactly alike. This irregularity in leaf-form, together with the peculiar fruit, makes the recognition of the mulberry easy. Often it is difficult to distinguish the two species.

Tulip Tree. Yellow Poplar. Whitewood

(Mich. Trees).

1. Winter twig, $\times 1$.
2. Leaf, $\times \frac{1}{2}$.
3. Flowering branchlet, $\times \frac{1}{2}$.
4. Fruit (opened and partly disseminated), $\times \frac{1}{2}$.

MAGNOLIACEAE**Tulip Tree. Yellow Poplar. Whitewood*****Liriodendron tulipifera* L.**

HABIT.—A large tree 50-70 feet high, with a columnar trunk 2-3 feet in diameter; forming a rather open, conical crown of slender branches.

LEAVES.—Alternate, simple, 5-6 inches long and broad; 4-lobed; entire; lustrous, dark green above, pale or glaucous beneath, turning clear yellow in autumn; petioles slender, angled, 5-6 inches long.

FLOWERS.—June, after the leaves; perfect; terminal; solitary on stout peduncles; tulip-shaped, greenish yellow, $1\frac{1}{2}$ -2 inches long; sepals 3, greenish, early deciduous; petals 6, in 2 rows, greenish yellow with an orange spot at the base, early deciduous; stamens numerous, somewhat shorter than the petals; pistils numerous, clinging together about a central axis; ovary 1-celled.

FRUIT.—September-October; a narrow, light brown cone $2\frac{1}{2}$ -3 inches long, composed of numerous carpels; carpels long, flat, with a 1-2-seeded nutlet at the base, separating from the slender spindle at maturity.

WINTER-BUDS.—Terminal bud $\frac{1}{2}$ -1 inch long, obtuse, flattish, dark red, covered with a glaucous bloom.

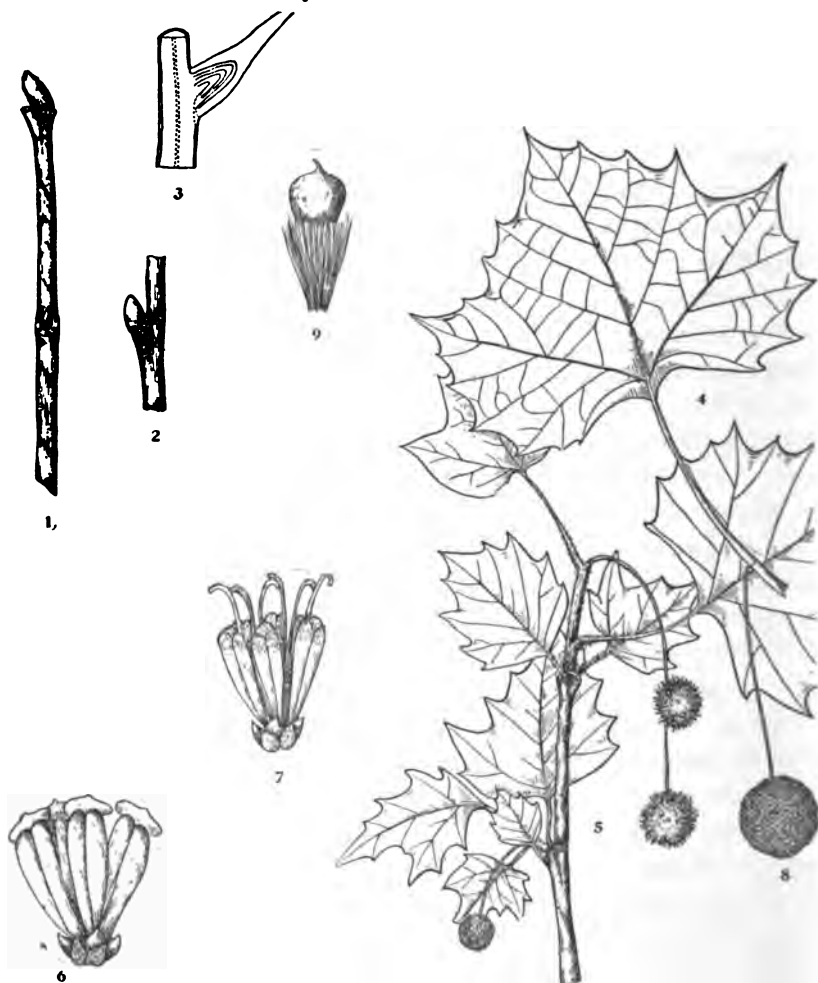
BARK.—Twigs smooth, lustrous, reddish, becoming brownish, and at length gray; ashy gray, thin and scaly on young trunks, becoming thick, brownish, and deeply furrowed with age. Plate VI.

WOOD.—Light, soft, brittle, weak, easily worked, light yellow or brown, with thin, cream-white sapwood.

DISTRIBUTION.—Hoosic valley in southwestern Vermont; rare.

HABITAT.—Prefers deep, rich, rather moist soil, but adapts itself readily to any good, light soil.

NOTES.—The tulip tree is included in this list of native Vermont trees, although few native trees can be pointed out. The tree was reported authentically in the Appendix to Thompson's "Vermont" in 1853. It then occurred occasionally in Bennington county along the Hoosic valley. A single native specimen of this species is reported from North Pownal by Eggleston, showing that it is not yet extinct. It is to be hoped that tree lovers located in that portion of Vermont will learn and more fully report upon its present distribution, as this region marks its northern limit as a native tree. It thrives, however, as a shade tree planted in Rutland and Burlington. An attractive feature of this tree is its display of tulip-like flowers which open in June.

Sycamore. Buttonwood

(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, side view, x 1.
3. Vertical section of twig, summer bud and leaf petiole, enlarged.
4. Leaf, x $\frac{3}{8}$.
5. Flowering branchlet, x $\frac{1}{2}$.
6. Staminate flower, enlarged.
7. Pistillate flower, enlarged.
8. Fruit, x $\frac{3}{8}$.
9. Achene, enlarged.

PLATANACEAE**Sycamore. Buttonwood*****Platanus occidentalis* L.**

HABIT.—A large tree 50-80 feet high, with a trunk diameter of 3-5 feet; commonly dividing near the ground into several large secondary trunks, forming a broad, open, irregular crown of massive, spreading branches.

LEAVES.—Alternate, simple, 5-10 inches long and broad; broadly ovate in outline; more or less 3-5-lobed by broad, shallow sinuses, the lobes sinuate-toothed; thin and firm; bright green above, paler beneath, glabrous both sides; petioles stout, puberulous, 1-2 inches long.

FLOWERS.—May, with the leaves; monoecious; borne in dense heads; the staminate dark red, on short, axillary peduncles; the pistillate greenish, on long, slender, terminal peduncles; sepals 3-6, minute; petals 3-6, minute; stamens 3-6, usually 4; styles long, incurved, red.

FRUIT.—October, persistent on the limbs through the winter; brown heads about 1 inch in diameter, on slender, glabrous stems 3-6 inches long.

WINTER-BUDS.—Terminal bud absent; lateral buds $\frac{1}{4}$ - $\frac{3}{8}$ inch long, conical, blunt, lustrous, pale brown; forming in summer within the petiole of the leaf.

BARK.—Twigs pale green and tomentose, becoming smooth, dark green, finally grayish; thick, red-brown on the trunk and broken into oblong, plate-like scales, separating higher up into thin plates which peel off, exposing the greenish or yellowish inner bark. Plate VI.

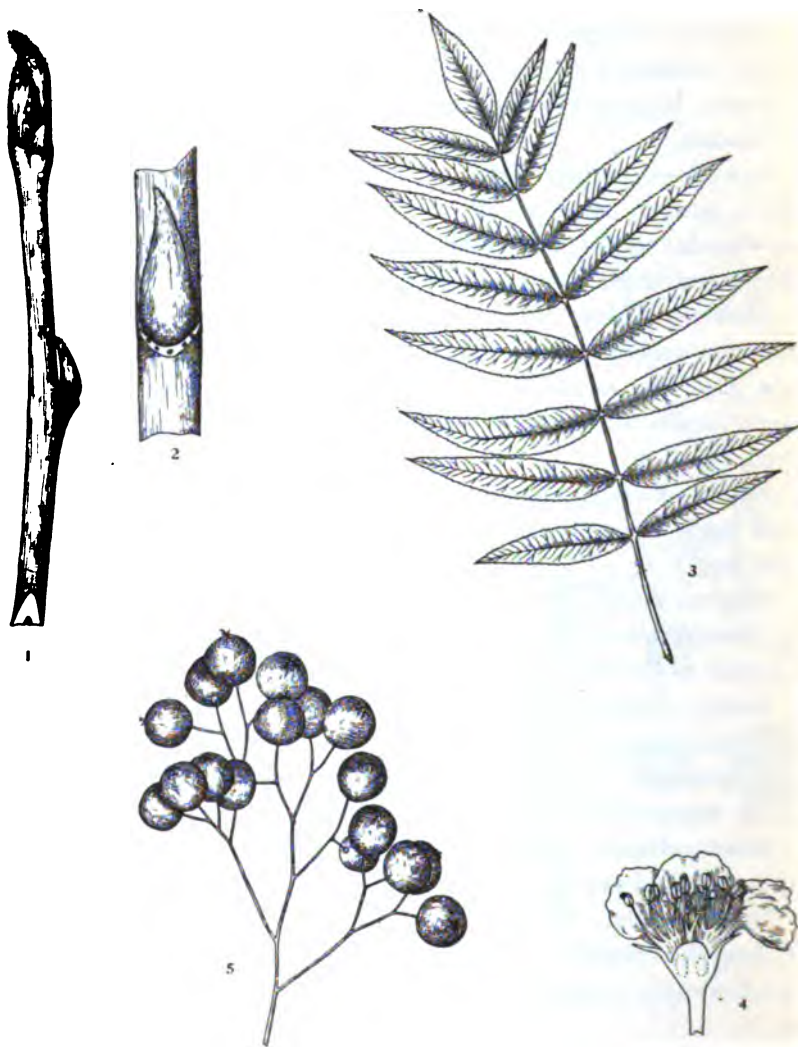
WOOD.—Heavy, tough, hard, rather weak, coarse-grained, difficult to split, light red-brown, with thick, darker colored sapwood.

DISTRIBUTION.—Occasional to frequent in the Champlain valley and along the tributary rivers, becoming abundant in the Hoosic valley in southwestern Vermont; Connecticut valley as far north as Hartford.

HABITAT.—Rich bottom-lands along the borders of rivers and lakes.

NOTES.—The bark unmistakably characterizes this species. On old trees this is brown and rough on the lower parts of the trunks, but above and on the branches it is smoother, with great, irregular, whitish or pale yellowish patches where the outer layers have scaled off, leaving the inner bark exposed. This gives the tree a whitewashed appearance when seen from a short distance.

American Mountain Ash



(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{1}{3}$.
4. Vertical section of flower, enlarged.
5. Portion of a fruiting cyme, x 1.

ROSACEAE

American Mountain Ash

Pyrus americana (Marsh.) DC. [*Sorbus americana* Marsh.]

HABIT.—A small tree 20-30 feet high, with a trunk diameter of 12-15 inches; branches slender, spreading, forming a narrow, rounded crown.

LEAVES.—Alternate, compound, 6-9 inches long. Leaflets 9-17, 2-3 inches long and $\frac{1}{2}$ - $\frac{3}{4}$ inch broad; sessile or nearly so, except the terminal; lanceolate to oblong-lanceolate, taper-pointed; finely and sharply serrate above the entire base; membranaceous; glabrous, dark yellow-green above, paler beneath, turning clear yellow in autumn. Petioles slender, grooved, enlarged at the base.

FLOWERS.—May-June, after the leaves; perfect; $\frac{1}{8}$ inch across; borne on short, stout pedicels in many-flowered, flat cymes 3-5 inches across; calyx urn-shaped, 5-lobed, puberulous; petals 5, white; stamens numerous; styles 2-3.

FRUIT.—October, but persistent on the tree throughout the winter; a berry-like pome, subglobose, $\frac{1}{4}$ inch in diameter, bright red, with thin, acid flesh; eaten by birds in the absence of other food.

WINTER-BUDS.—Terminal bud about $\frac{1}{2}$ inch long, ovoid, acute, with curved apex; lateral buds smaller, appressed; scales rounded on the back, purplish red, more or less pilose above, gummy.

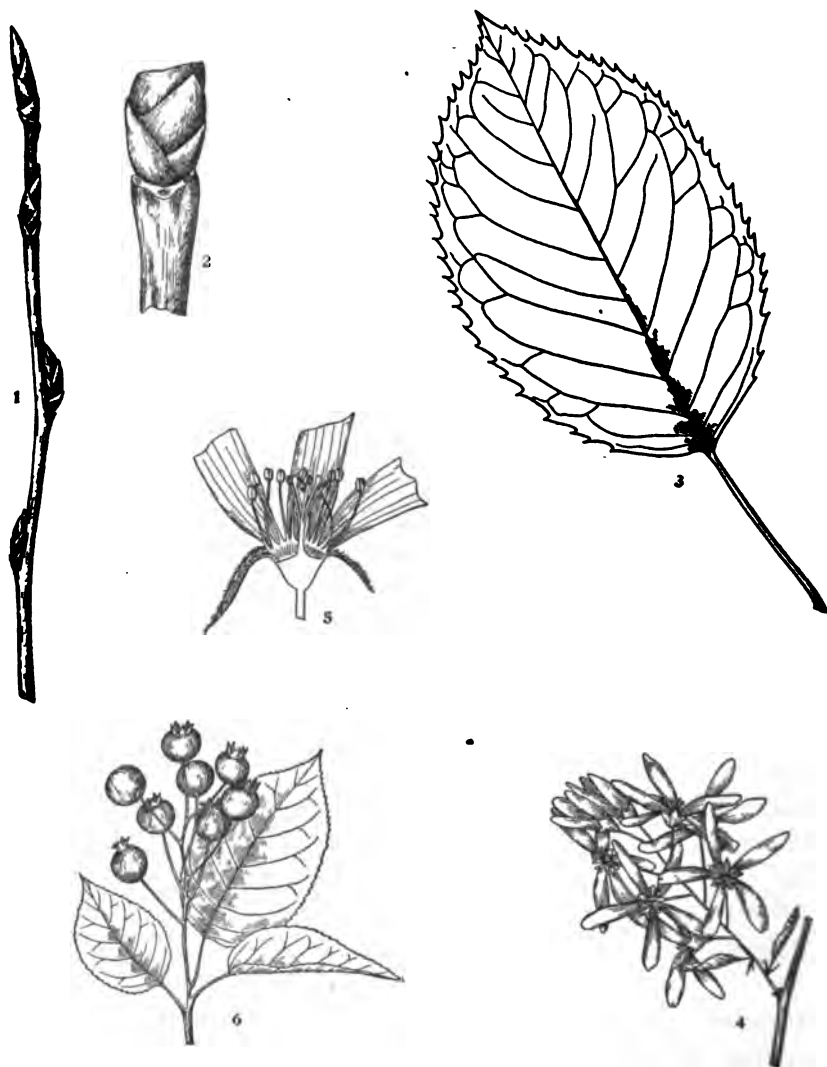
BARK.—Twigs at first red-brown and hairy, becoming glabrous, dark brown; thin, light gray-brown on the trunk, smooth, or slightly roughened on old trees; inner bark fragrant.

WOOD.—Light, soft, close-grained, weak, pale brown, with thick, lighter colored sapwood.

DISTRIBUTION.—Frequent throughout Vermont, becoming common in the mountainous sections.

HABITAT.—Rich, moist soil on river-banks and on the borders of cold swamps; rocky hillsides and mountains.

NOTES.—This is one of the most beautiful trees of our northern forests. It is conspicuous among our trees for broad, flat-topped clusters of creamy white flowers followed by the persistent scarlet fruits. The common name is suggested by the general resemblance of the compound leaf to that of the ashes. In reality these trees are very closely related to the cultivated apples and pears, a fact which will become evident if one examines the structure of either the flower or the apple-like fruit. The European mountain ash, *Pyrus aucuparia* (L.) Ehrh. is planted commonly in Vermont for ornamental purposes and plants of this species are abundantly spontaneous in several localities.

Shadbush. Juneberry. Service Berry

(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x 1.
4. Flowering branchlet, x $\frac{1}{2}$.
5. Vertical section of flower, enlarged.
6. Fruiting branchlet, x $\frac{1}{2}$.

ROSACEAE

Shadbush. Juneberry. Service Berry

Amelanchier canadensis (L.) Medic.

HABIT.—A shrub or small tree 15-30 feet in height, with a tall trunk 6-12 inches in diameter; forming a narrow, rounded crown of many small limbs and slender branchlets.

LEAVES.—Alternate, simple, 3-4 inches long and about one-half as broad; ovate to obovate; finely and sharply serrate; glabrous, dark green above, paler beneath; petioles slender, about 1 inch long.

FLOWERS.—April-May, when the leaves are about one-third grown; perfect; large, white, borne in drooping racemes 3-5 inches long; calyx 5-cleft, campanulate, villous on the inner surface; petals 5, strap-shaped, white, about 1 inch in length; stamens numerous; styles 5, united below.

FRUIT.—June-August; globular, berry-like pome, $\frac{1}{3}$ - $\frac{1}{2}$ inch long; turning from bright red to dark purple with slight bloom; sweet and edible when ripe.

WINTER-BUDS.—Yellow-brown, narrow-ovoid to conical, sharp-pointed, $\frac{1}{4}$ - $\frac{1}{2}$ inch long; bud-scales apiculate, slightly pubescent.

BARK.—Twigs smooth, light green, becoming red-brown; thin, pale red-brown on the trunk, smoothish or divided by shallow fissures into narrow, longitudinal, scaly ridges.

WOOD.—Heavy, very hard, strong, close-grained, dark red-brown, with thick, lighter colored sapwood.

DISTRIBUTION.—Common throughout Vermont, especially in the Champlain valley.

HABITAT.—Dry, upland woods and hillsides; light soils.

NOTES.—Several other species occur in Vermont, most of which are shrubs below tree height. One is a small tree, however, becoming shrubby in the north. It differs but slightly from *Amelanchier canadensis* and until recently has not been distinguished from it. This new species has been named *Amelanchier laevis* Wiegand. It is said to be more northerly in its distribution than *Amelanchier canadensis*. The shadbush is easily recognized by its graceful white flowers which appear in the most lavish profusion in May before those of any other native fruit tree. The fruits which ripen in June are nearly one-half an inch long, purple, sweet and edible, but the birds make way with them so quickly that they are not often to be found. The shadbush is common in light soils and dry woodlands throughout Vermont, and especially so in parts of the Champlain valley. It ranges in size and habit from a bush to a small tree twenty to thirty feet in height.

Dotted Haw

(Mich. Trees).

1. Winter twig, $\times 1$.
2. Leaf, $\times 1$.
3. Flowering branchlet, $\times \frac{1}{2}$.
4. Vertical Section of flower, enlarged.
5. Fruit, $\times 1$.

ROSACEAE**Hawthorns or Thorn-apples*****Crataegus* L.**

Owing to the complexity of the various forms in this group, the present state of uncertainty as to the value of certain characters, and the questionable validity of many of the assigned names, it is thought to be beyond the scope of this bulletin to give more than a general description of the group as a whole, recommending the more ambitious student to the various manuals and botanical journals and papers for more detailed information.

The *Crataegi* are generally low, wide-spreading trees or shrubs, with strong, tortuous branches and more or less zigzag branchlets usually armed with stiff, sharp thorns. The bark varies from dark red to gray and is shallowly fissured or scaly. The leaves are alternate, simple, generally serrate, often lobed, with short or long petioles. The flowers appear in May or June, with or after the leaves, in simple or compound corymbs, whitish or pinkish, perfect. The fruit is a red to yellow, sometimes blue or black pome, subglobose to pear-shaped, with usually dry and mealy flesh and 1-5 seeds. The winter-buds are small, nearly globose, lustrous brown. *Crataegus* produces wood which is heavy, hard, tough, close-grained, red-brown, with thick, pale sapwood. The hawthorns are trees of the pasture-lands, the roadside, the open woods and the stream-banks, and are more common in the southern part of Vermont and in the lower altitudes, although some few species extend northward into Canada and some are found at considerable altitudes. Some of the species are desirable as ornaments in parks and gardens on account of their beautiful and abundant flowers and showy fruits.

THE PLUMS AND CHERRIES

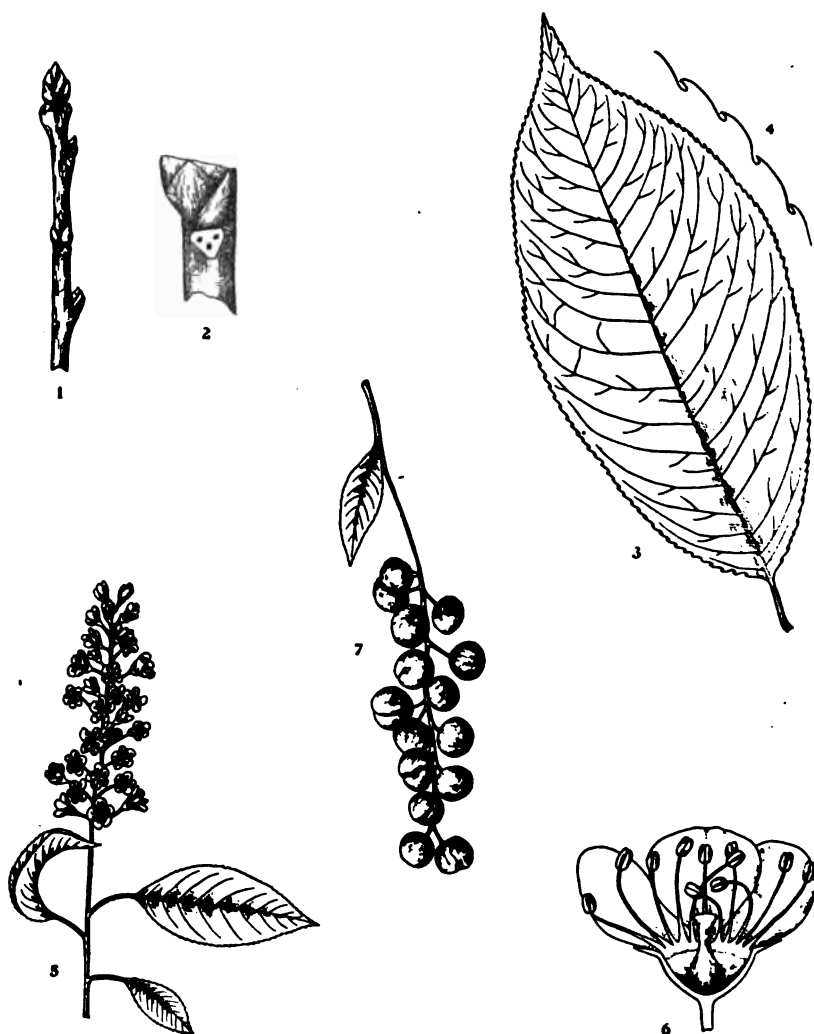
The plums and cherries, particularly when in blossom, are among the most attractive trees in New England. They are all of small or medium size with conspicuous pink or white flowers. They are distinguished by their stone fruit and by their astringent bark and leaves. Seven species are found in Vermont. Only four of these are described in this bulletin. One of these, the choke cherry, seldom attains to the size or habit of a tree, but it is deemed best to include it here since it occurs so commonly along with the tree species that the omission might lead to some confusion.

SUMMER KEY TO THE SPECIES OF PRUNUS

- a. Leaves oblong-ovate to obovate, abruptly acuminate at the apex; marginal teeth not incurved.
 - b. Margin of leaves sharp-serrate with spreading teeth; leaves not rugose, the veins not prominent; fruit $\frac{1}{4}$ - $\frac{1}{2}$ inch long, bright red, racemose, July-August; bark of trunk brown, smooth or only slightly fissured; usually a large shrub,
 - P. virginiana**, p. 153.
 - bb. Margin of leaves crenate-serrate; leaves more or less rugose, the veins prominent; fruit about 1 inch long, orange-red, clustered, August-September; bark of trunk gray-brown, early splitting off in large, thick plates; a small tree.....**P. nigra**, p. 157.
- aa. Leaves oval to oblong-lanceolate, taper-pointed at the apex; marginal teeth incurved.
 - b. Fruit light red, clustered, July-August; twigs usually less than $\frac{1}{16}$ inch thick; pith of twigs brown... **P. pennsylvanica**, p. 155.
 - bb. Fruit black, racemose, August-September; twigs usually more than $\frac{1}{16}$ inch thick; pith of twigs white...**P. serotina**, p. 151.

WINTER KEY TO THE SPECIES OF PRUNUS

- a. Terminal bud present; bark of young trunks rather smooth.
 - b. Buds clustered at the tips of all shoots; twigs usually less than $\frac{1}{16}$ inch thick; pith of twigs brown...**P. pennsylvanica**, p. 155.
 - bb. Buds not clustered, or clustered only on short, spur-like branchlets; twigs usually more than $\frac{1}{16}$ inch thick; pith of twigs white.
 - c. Buds usually $\frac{1}{4}$ inch or less in length; bud-scales uniform in color, apiculate at the apex; bark on old trunks blackish, rough-scaly; small to large tree.....**P. serotina**, p. 151.
 - cc. Buds usually $\frac{1}{4}$ - $\frac{1}{2}$ inch long; bud-scales grayish on the margins, rounded at the apex; bark on old trunks brown, smooth or only slightly fissured; usually a large shrub,
 - P. virginiana**, p. 153.
- aa. Terminal bud absent; bark of young trunks early splitting off in large, thick plates**P. nigra**, p. 157.

Black Cherry

(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{3}{4}$.
4. Margin of leaf, enlarged.
5. Flowering branchlet, x $\frac{1}{2}$.
6. Vertical section of flower, enlarged.
7. Fruiting branchlet, x $\frac{1}{2}$.

ROSACEAE

Black Cherry

Prunus serotina Ehrh. [*Padus serotina* (Ehrh.) Agardh.]

HABIT.—A medium-sized tree 30-50 feet high and 8-24 inches in trunk diameter; branches few, large, tortuous, forming a rather spreading, oblong or rounded crown.

LEAVES.—Alternate, simple, 2-5 inches long, about one-half as broad; oval or oblong to oblong-lanceolate; finely serrate, with teeth incurved; subcoriaceous; dark green and very lustrous above, paler beneath, glabrous both sides; petioles short, slender, usually bearing 2 red glands near the blade.

FLOWERS.—May-June, when the leaves are half grown; perfect; $\frac{1}{4}$ inch across; borne on slender pedicels in many-flowered, loose racemes 4-5 inches long; calyx cup-shaped, 5-lobed; petals 5, white; stamens 15-20; stigma thick, club-shaped.

FRUIT.—August-September; a globular drupe, $\frac{1}{3}$ - $\frac{1}{2}$ inch in diameter, nearly black, with dark purple, juicy flesh; slightly bitter, edible.

WINTER-BUDS.—Terminal bud about $\frac{1}{4}$ inch long, ovoid, blunt to acute; scales keeled on the back, apiculate, light brown.

BARK.—Twigs and branches red to red-brown; young trunks dark red-brown, smooth; blackish on old trunks and rough, broken into thick, irregular plates; bitter, aromatic. Plate VI.

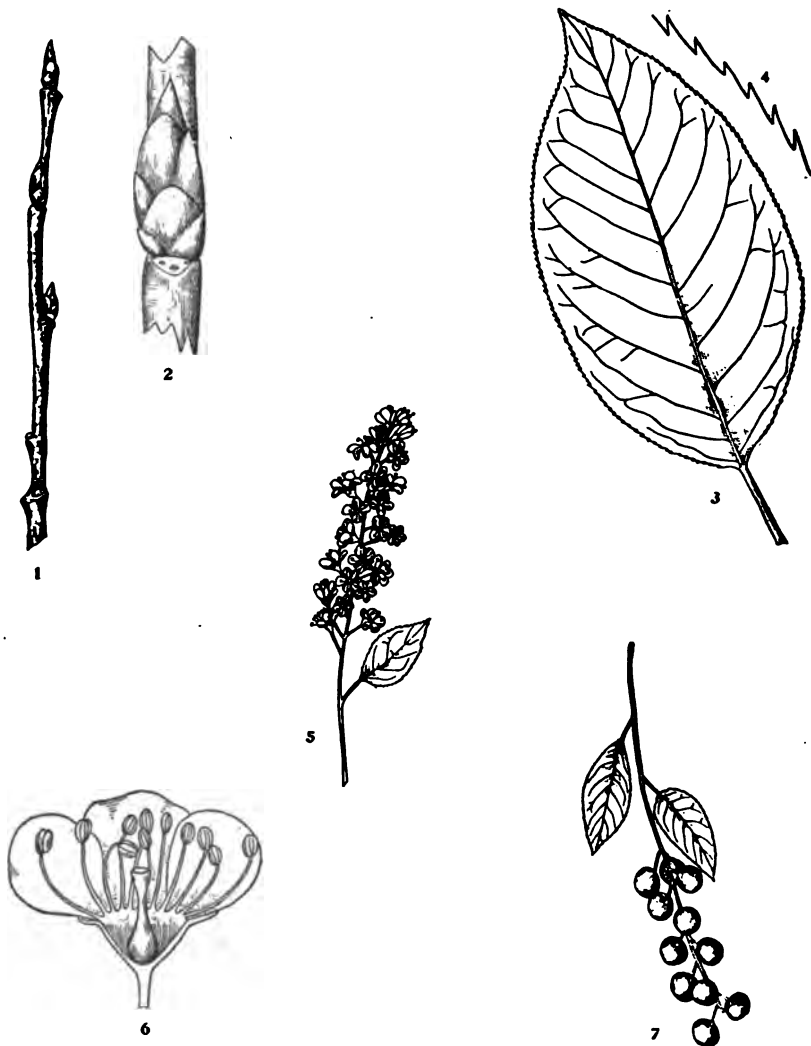
WOOD.—Light, rather hard, strong, close- and straight-grained, light brown or red, with thin, yellow sapwood.

DISTRIBUTION.—Common throughout Vermont.

HABITAT.—Woodlands; in all sorts of soils and exposures.

NOTES.—This is the only native Vermont cherry which reaches a sufficient size to make it a valuable timber tree. It has been exported in considerable quantities from the southern part of Vermont, but now large trees are seldom found. The wood is of very superior quality for cabinet making, and commands the highest price of any native American timber. It has a beautiful grain and takes a very fine polish. The flowers resemble other cherry blossoms and are borne in racemes. The fruit at first is dark red, then becomes almost black, with a thick skin and dark juicy flesh, which generally is rather bitter but sometimes sweet and pleasant.

Choke Cherry



(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x 1.
4. Margin of leaf, enlarged.
5. Flowering branchlet, x $\frac{1}{2}$.
6. Vertical section of flower, enlarged.
7. Fruit, x $\frac{1}{2}$.

ROSACEAE

Choke Cherry

***Prunus virginiana* L.** [*Padus virginiana* (L.) Roemer]

HABIT.—Usually a large shrub, but sometimes a small tree 15-25 feet high, with a crooked, often leaning trunk 5-6 inches in diameter; forming a spreading, somewhat rounded crown.

LEAVES.—Alternate, simple, 2-4 inches long, one-half as broad; obovate to oblong-obovate or oval, abruptly acuminate at the apex; finely and sharply serrate; dull dark green above, paler beneath, glabrous both sides; petioles short, slender, glandular at the apex.

FLOWERS.—May-June, when the leaves are half grown; perfect; about $\frac{1}{2}$ inch across; borne on short, slender pedicels in many-flowered racemes 3-6 inches long; calyx cup-shaped, 5-lobed; petals 5, white; stamens 15-20; stigma broad, on a short style.

FRUIT.—July-August; a globular drupe, $\frac{1}{4}$ - $\frac{1}{2}$ inch in diameter, usually bright red, often yellow to almost black; with dark red flesh; astringent, but edible.

WINTER-BUDS.—Terminal bud $\frac{1}{4}$ - $\frac{1}{2}$ inch long, conical, acute; scales rounded at the apex, light brown, smooth.

BARK.—Twigs at first light brown or greenish, becoming red-brown, finally dark brown; thin, dark brown on the trunk, slightly fissured.

WOOD.—Heavy, hard, close-grained, weak, light brown, with thick, lighter colored sapwood.

DISTRIBUTION.—Common throughout Vermont, even on the higher mountains.

HABITAT.—Fence-rows, woods and banks.

NOTES.—The choke cherry is the most widely distributed tree of North America, extending from the Arctic circle to Mexico, from the Rocky mountains to the Atlantic ocean. *Prunus virginiana leucocarpa*, a variety with short, dense racemes of flowers and sweet, yellowish fruit, has been reported from Lunenburg and Franklin. The choke cherry usually is a shrub in Vermont. It is included, however, in this list of trees because of its close relationship to the other cherries. In May, when the leaves are half grown, it is covered with creamy white flowers in long nodding clusters. The peculiarly astringent fruit, varying greatly in quality, however, ripens abundantly in August. It makes a good quality of jelly.

Wild Red Cherry. Bird Cherry. Pin Cherry



(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x 1.
4. Margin of leaf, enlarged.
5. Flowering branchlet, x $\frac{1}{2}$.
6. Flower, enlarged.
7. Fruit, x 1.

ROSACEAE

Wild Red Cherry. Bird Cherry. Pin Cherry

Prunus pennsylvanica L. f.

HABIT.—A slender tree, seldom over 30 feet high, with a trunk diameter of 8-10 inches; crown rather open, narrow, rounded, with slender, regular branches.

LEAVES.—Alternate, simple, 3-5 inches long, $\frac{3}{4}$ -1 $\frac{1}{4}$ inches broad; oblong-lanceolate; finely and sharply serrate; bright green and shining above, paler beneath; petioles slender, $\frac{1}{2}$ -1 inch long, glandular near the blade.

FLOWERS.—April-May, with the leaves; perfect; about $\frac{1}{2}$ inch across, borne on slender pedicels in 4-5-flowered umbels, generally clustered, 2-3 together; calyx 5-cleft, campanulate; petals 5, white, $\frac{1}{4}$ inch long; stamens 15-20.

FRUIT.—July-August; a globular drupe, $\frac{1}{4}$ inch in diameter, light red, with thick skin and sour flesh.

WINTER-BUDS.—Terminal bud $\frac{1}{8}$ inch long, broadly ovoid, rather blunt, brownish, smooth.

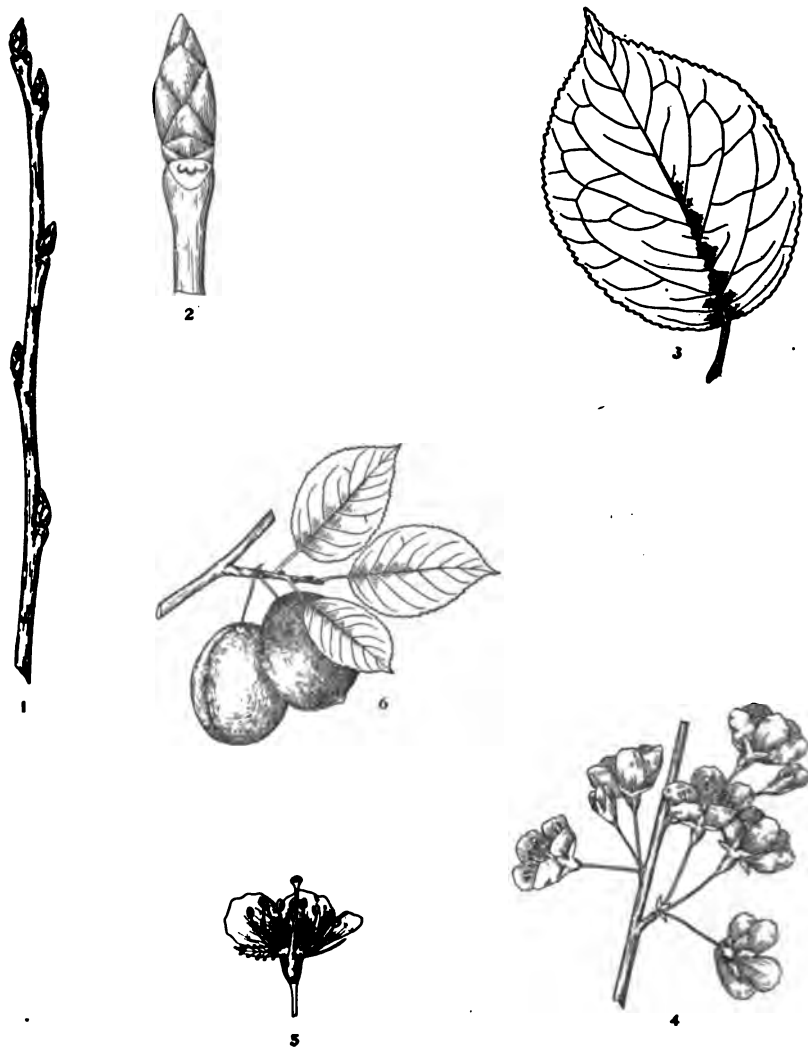
BARK.—Twigs at first lustrous, red, marked by orange colored lenticels, becoming brownish; red-brown and thin on the trunk, peeling off horizontally into broad, papery plates; bitter, aromatic.

WOOD.—Light, soft, close-grained, light brown, with thin, yellow sapwood.

DISTRIBUTION.—Common throughout Vermont, even on the higher mountains.

HABITAT.—Roadsides; burned-over lands; clearings; hillsides.

NOTES.—The wild red cherry, a small, slender tree, is distributed quite generally from the rocky woods of Newfoundland to North Carolina. It is common in all parts of Vermont where often it is only a roadside shrub. The flowers appear in May on long pedicels in beautiful white clusters. The fruit, which ripens in midsummer, is small and globular, becoming bright red when mature. This tree is distinguished from the other cherries by its slender and more graceful form, by its lighter colored, close-growing bark, often covered with transverse scars (lenticels), by its small flowers in spreading clusters and by its very small globular fruit similarly clustered.

Wild Plum. Canada Plum

(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{1}{2}$.
4. Flowering branchlet, x $\frac{1}{2}$.
5. Vertical section of flower, enlarged.
6. Fruiting branchlet, x $\frac{1}{2}$.

ROSACEAE**Wild Plum. Canada Plum**

***Prunus nigra* Ait.** [*Prunus americana*, v. *nigra* Waugh]

HABIT.—A small tree 20-25 feet high and 5-8 inches in trunk diameter; usually divides 5-6 feet from the ground into a number of stout, upright branches, forming a narrow, rigid crown.

LEAVES.—Alternate, simple, 3-5 inches long and one-half as broad; oblong-ovate to obovate, abruptly acuminate at the apex; doubly crenate-serrate; thick and firm; glabrous, light green above, paler beneath; petioles short, stout, bearing 2 large red glands near the blade.

FLOWERS.—April-May, before the leaves; perfect; slightly fragrant; about 1 inch across; borne on slender, glabrous, red pedicels in 2-3-flowered umbels; calyx 5-lobed, dark red; petals 5, white; stamens 15-20, with purple anthers; ovary 1-celled; style 1; stigma 1.

FRUIT.—August-September; a fleshy drupe, about 1 inch long, oblong-ovoid, with a tough, thick, orange-red skin nearly free from bloom, and yellow flesh adherent to the flat stone. Eaten raw or cooked.

WINTER-BUDS.—Terminal bud absent; lateral buds $\frac{1}{8}$ - $\frac{1}{4}$ inch long, ovate, acute, chestnut-brown.

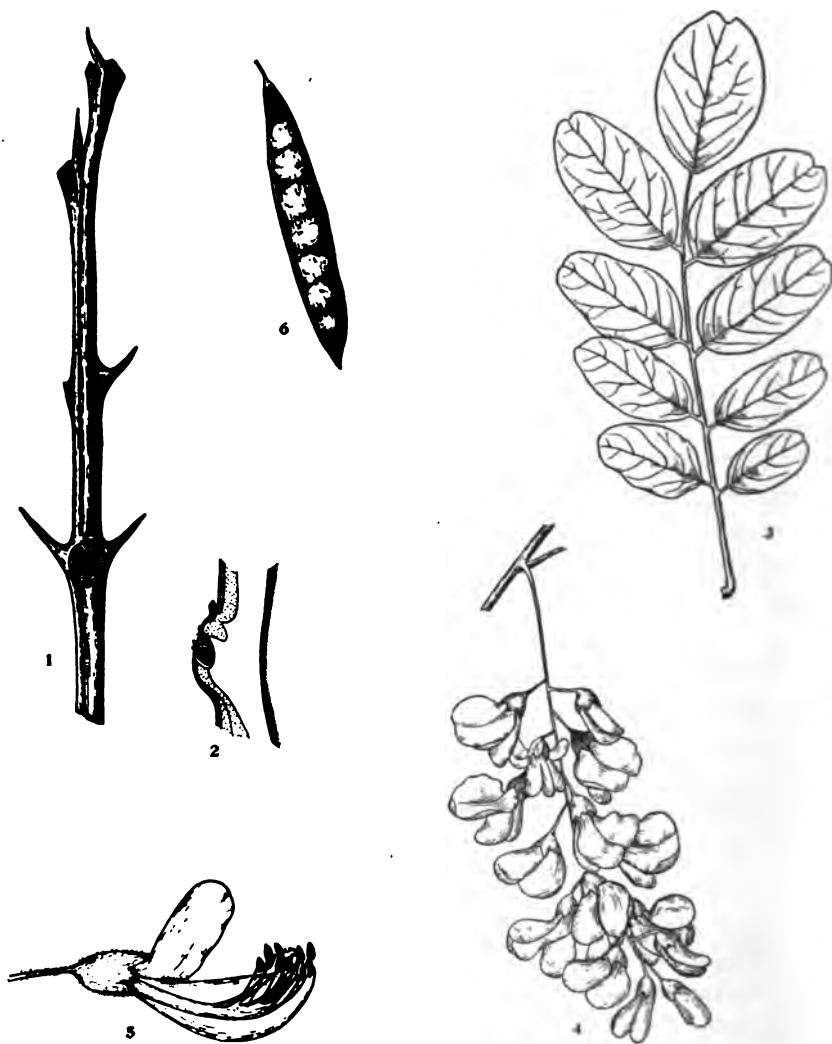
BARK.—Twigs green, marked by numerous pale excrescences, later dark brown; thin, gray-brown and smooth on young trunks, but soon splitting off in large, thick plates, exposing the darker inner bark.

WOOD.—Heavy, hard, strong, close-grained, light red-brown, with thin, lighter colored sapwood.

DISTRIBUTION.—Frequent, especially in the northern portion of the state; never native in eastern Vermont.

HABITAT.—Woods; fence-rows.

NOTES.—The Canada plum, found frequently in Vermont, is a small tree or shrub, with gray-brown bark and short, spiny branchlets. It may be recognized by its broad, coarse leaves, sometimes four inches long and two or three inches wide. The flowers are abundant, large and strong, of a fine pinkish color, and appear about the first week in May. The fruit, often an inch in diameter, ripens in August. It is sometimes rather bitter, but occasional trees bear good eatable fruit.

Common Locust. False Acacia

(Mich. Trees).

1. Winter twig, x 1.
2. Vertical section through lateral bud, enlarged.
3. Leaf, x $\frac{1}{2}$.
4. Raceme of flowers, x $\frac{1}{2}$.
5. Flower, with part of corolla removed, enlarged.
6. Fruit, x $\frac{1}{2}$.

LEGUMINOSAE**Common Locust. False Acacia*****Robinia pseudo-acacia* L.**

HABIT.—A tree 50-75 feet high, with a trunk diameter of 2-3 feet; usually smaller; forming a narrow, oblong crown of irregular, more or less contorted branches.

LEAVES.—Alternate, compound, 8-14 inches long. Leaflets 7-21, short-petiolate, 1-2 inches long, about one-half as broad; ovate to oblong-oval; entire; very thin; dull dark green above, paler beneath, glabrous both sides. Petioles slender, pubescent.

FLOWERS.—June, after the leaves; perfect; showy and abundant; very fragrant; borne on slender pedicels in loose, drooping racemes 4-5 inches long; about 1 inch long; calyx short, bell-shaped, 5-lobed, hairy; corolla papilionaceous, white, 5-petaled; stamens 10.

FRUIT.—Late autumn, but persistent on the tree through the winter; a smooth, dark brown, flat pod 3-4 inches long, containing 4-8 small, flattish, brown seeds.

WINTER-BUDS.—Terminal bud absent; lateral buds minute, 3-4 superposed, partially sunken within the leaf-scar, rusty-hairy.

BARK.—Twigs smooth, green, more or less rough-dotted at first, becoming red-brown and armed with prickles; dark red-brown and thick on old trunk, deeply furrowed into firm, sinuous ridges. Plate VI.

WOOD.—Heavy, very strong and hard, close-grained, very durable in contact with the soil, brown, with very thin, pale yellow sapwood.

NOTES.—The common locust is a native of Pennsylvania and the more southern states. It has been widely planted in Vermont and frequently has run wild along fence-rows and about yards. The profusion of the fragrant, white, pea-like blossoms, the delicacy of the foliage and the picturesque form of the tree combine to make it very attractive. This locust is a large, rapidly growing tree, but it is attacked by borers and probably cannot be successfully grown in Vermont.

THE MAPLES

The maple family is a large one including nearly seventy species. Ten of these occur in the United States, and seven are found in Vermont. In many respects they form the most characteristic feature of our forest flora, and were Vermonters to select a state tree, popular choice certainly would be unanimous for the sugar maple.

The maples are distinguished easily from all other trees by their peculiar winged or "key" fruit. The leaves of all except the ash-leaved maple also are so similar as to form a good family character.

Two of the seven native species are as frequently shrubby as they are tree-like both in size and habit of growth, but all are included in this bulletin. By appealing to the size of the tree and characters of the leaves it is possible to distinguish the species.

Introduced species.—The Norway maple is a European species frequently used as a street shade tree farther south, and occasionally planted in Vermont. It most closely resembles the sugar maple among our native species but is easily distinguished by its broader and lower crown, larger leaves and larger, more divergent key-fruits.

Numerous horticultural varieties of the silver maple have been introduced in recent years, especially from Japan. These include very deeply cut-leaved forms, and also one with drooping branches. Their relationship to the native species is usually recognizable however.

The horse-chestnuts and buckeyes are closely related to the maples, although some authorities place them in a separate family. Of these the common horse-chestnut (*Aesculus hippocastanum*) is very commonly cultivated. It forms a large, clean, symmetrical tree, with rich foliage and showy blossoms. The buckeyes of the south and west are occasionally planted.

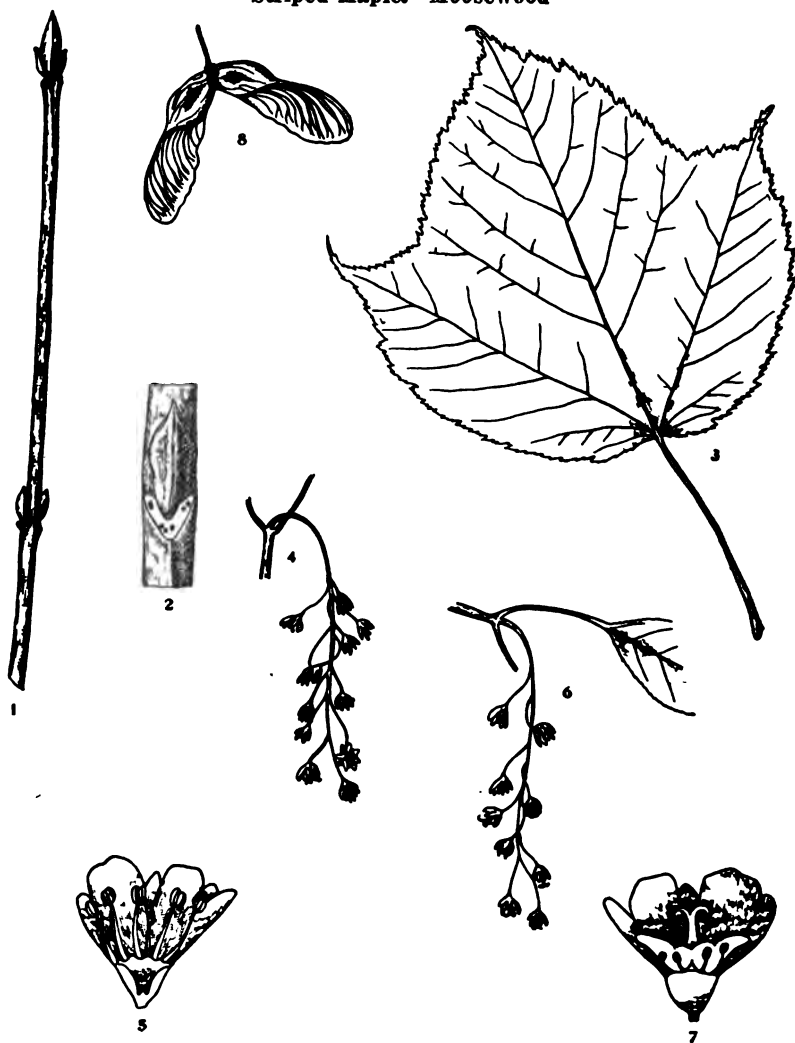
SUMMER KEY TO THE SPECIES OF ACER

- a. Leaves simple; twigs usually without whitish bloom.
 - b. Leaf-sinuses acute at the base.
 - c. Leaf-lobes long and narrow, the sides of the terminal lobe diverging; leaves silvery white beneath; twigs rank-smelling when broken **A. saccharinum**, p. 173.
 - cc. Leaf-lobes short and broad, the sides of the terminal lobe converging; leaves not conspicuously white beneath; twigs not rank-smelling when broken.
 - d. Leaves distinctly white-downy beneath; twigs appressed-hairy, at least near the tip; fruit hanging in pendulous racemes, persistent on the tree until autumn; seed portion with pit-like depression on one side; usually a shrub or bushy tree **A. spicatum**, p. 167.
 - dd. Leaves glabrous or nearly so beneath; twigs glabrous; fruit hanging in clusters, falling in early summer; seed portion without pit-like depression on one side; medium-sized tree **A. rubrum**, p. 175.
 - bb. Leaf-sinuses rounded at the base.
 - c. Lower sides of leaves and petioles distinctly downy, the lobes undulate or entire; leaves very thick, drooping at the sides, **A. saccharum nigrum**, p. 171.
 - cc. Lower sides of leaves and petioles essentially glabrous, the lobes serrate; leaves not thick, not drooping at the sides.
 - d. Leaves coarsely and sparsely toothed or notched; bark not longitudinally white-striped; fruit not in racemose clusters; large tree **A. saccharum**, p. 169.
 - dd. Leaves finely and abundantly toothed; bark longitudinally white-striped; fruit in racemose clusters; a bushy tree or shrub **A. pennsylvanicum**, p. 165.
- aa. Leaves compound; twigs usually with whitish bloom, **A. negundo**, p. 177.

WINTER KEY TO THE SPECIES OF ACER

- a. Terminal buds usually under $\frac{1}{4}$ inch in length, not conspicuously stalked; bark not longitudinally white-striped.
 - b. Buds white-woolly; twigs usually with a whitish bloom; opposite leaf-scars meeting; fruit often persistent on the tree until spring **A. negundo**, p. 177.
 - bb. Buds not white-woolly; twigs without whitish bloom; opposite leaf-scars not meeting; fruit not persistent on the tree in winter.
 - c. Buds reddish or greenish; twigs bright red.
 - d. Twigs strictly glabrous; buds glabrous; spherical flower buds clustered on the sides of the shoot; pith pink; large trees.
 - e. Twigs rank-smelling when broken; tip of outer bud-scales often apiculate; tips of branches curving upwards; bark separating into long, thin flakes loose at the ends,
 - A. saccharinum**, p. 173.
 - ee. Twigs not rank-smelling when broken; tip of outer bud-scales rounded; tips of branches not conspicuously curving upwards; bark rough-ridged, but seldom forming loose flakes **A. rubrum**, p. 175.
 - dd. Twigs appressed-hairy, at least near the tip; buds somewhat tomentose; spherical flower buds absent; pith brown; shrub or bushy tree..... **A. spicatum**, p. 167.
 - cc. Buds brownish; twigs brownish or grayish.
 - d. Buds glabrous, or somewhat pubescent at the apex only; bark dark gray on the trunk..... **A. saccharum**, p. 169.
 - dd. Buds hoary-pubescent; bark sometimes almost black on the trunk **A. saccharum nigrum**, p. 171.
- aa. Terminal buds usually $\frac{1}{4}$ - $\frac{1}{2}$ inch in length, conspicuously stalked; bark longitudinally white-striped... **A. pennsylvanicum**, p. 165.

Striped Maple. Moosewood



(Mich. Trees).

1. Winter twig, $\times 1$.
2. Portion of twig, enlarged.
3. Leaf, $\times \frac{1}{2}$.
4. Staminate flowering branchlet, $\times \frac{1}{2}$.
5. Vertical section of staminate flower, enlarged.
6. Pistillate flowering branchlet, $\times \frac{1}{2}$.
7. Vertical section of pistillate flower, enlarged.
8. Fruit, $\times \frac{3}{4}$.

ACERACEAE**Striped Maple. Moosewood*****Acer pennsylvanicum* L.**

HABIT.—A small tree at best, more often a large shrub, seldom attaining a height of more than 20 feet, with a short trunk 5-8 inches through. The striped, upright branches form a rather compact crown.

LEAVES.—Opposite, simple, 5-6 inches long and nearly as broad; 3-lobed above the middle with short, tapering lobes; palmately 3-nerved; sharply doubly serrate; rounded or heart-shaped at the base; glabrous, yellow-green above, paler beneath, turning pale yellow in autumn; petioles stout, grooved.

FLOWERS.—May-June, when the leaves are nearly full grown; usually monoecious; large bright yellow, bell-shaped, in slender, drooping racemes 4-6 inches long; calyx 5-parted; petals 5; stamens 7-8; ovary downy.

FRUIT.—Ripens in autumn; glabrous, paired samaras in long, drooping, racemose clusters, the wings $\frac{3}{4}$ inch long, widely divergent, and marked on one side of each nutlet by a small cavity.

WINTER-BUDS.—Bright red; terminal bud nearly $\frac{1}{2}$ inch long, short-stalked, with bud-scales keeled; lateral buds smaller, appressed.

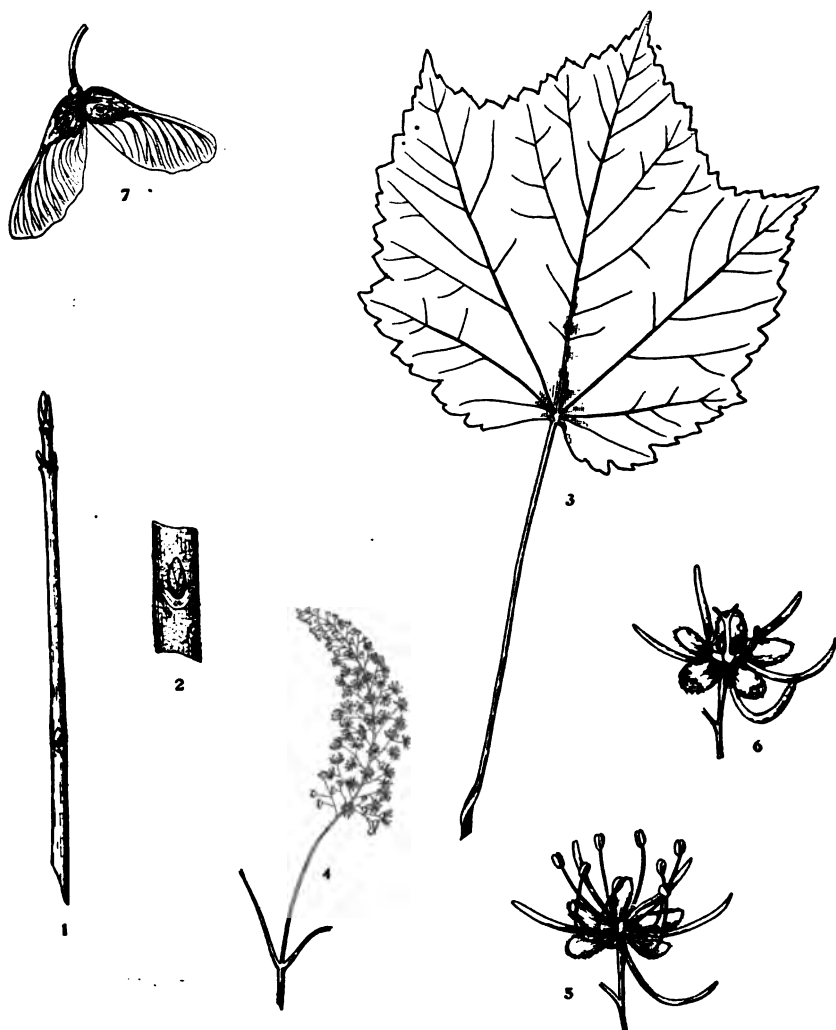
BARK.—Twigs light green, mottled with black, smooth; trunk and branches red-brown, marked longitudinally by broad, pale stripes.

WOOD.—Light, soft, close-grained, pinkish brown, with thick, lighter colored sapwood.

DISTRIBUTION.—Common throughout Vermont.

HABITAT.—Cool, rocky or sandy woods, in rich soil, usually in the shade of other trees.

NOTES.—The striped maple is a small tree or shrub which forms a familiar part of the undergrowth of our forests, and is a common roadside bush in all parts of Vermont. It is easily distinguished by its greenish bark striped longitudinally with darker lines. The leaves, the largest of the maples, are usually from five to seven inches long and four or five inches wide. Its drooping clusters of greenish flowers unfold by the middle of June when the leaves are nearly grown. The fruits are abundant and turn a beautiful scarlet towards autumn. This maple rarely exceeds a height of twenty feet. It also has a distinct value for ornamental planting, especially in groups or borders.

Mountain Maple

(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{1}{2}$.
4. Flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flower, enlarged.
7. Fruit, x 1.

ACERACEAE**Mountain Maple*****Acer spicatum* Lam.**

HABIT.—A bushy tree sometimes 20 feet high, with a short trunk 4-6 inches in diameter; small, upright branches form a small, rounded crown. More often a straggling shrub.

LEAVES.—Opposite, simple, 4-5 inches long and two-thirds as broad; 3-lobed above the middle, the lobes coarsely crenate-serrate with pointed teeth, the sinuses usually wide-angled and acute at the base; thin; glabrous, dark green above, covered with a whitish down beneath, turning scarlet and orange in autumn; veining prominent; petioles long, slender, with enlarged base.

FLOWERS.—May-June, after the leaves are full grown; polygamo-monoecious; small, yellow-green, in erect, slightly compound, many-flowered, long-stemmed, terminal racemes; calyx downy, 5-lobed; petals 5; stamens 7-8; ovary tomentose.

FRUIT.—July-August; bright red, turning brown in late autumn; small, glabrous, paired samaras, in pendulous, racemose clusters.

WINTER-BUDS.—Small, flattish, acute, bright red, more or less tomentose; the terminal $\frac{1}{8}$ inch long, containing the flowers.

BARK.—Twigs reddish, slightly hairy; very thin, red-brown, smooth or slightly furrowed on the trunk.

WOOD.—Light, soft, close-grained, light brown, with thick, lighter colored sapwood.

DISTRIBUTION.—Of common occurrence throughout Vermont.

HABITAT.—Damp mountain forests; rocky woods; along streams and roadsides; cool ravines; always in the shade of other trees.

NOTES.—The mountain maple rarely becomes more than a shrub in Vermont. It occurs commonly in moist, rocky, mountain forests in all parts of the state. Like the striped maple it is partial to roadsides, and borders all our mountain driveways. The leaves are thin and downy on the under side. The yellowish green flowers are borne in erect pubescent clusters which appear in the latter part of June. It is the spike-like arrangement of these flowers which suggested the Latin name of the species. The fruits are very divergent, smaller than those of any other maple and become bright red in July and August. The heavy clusters then hang down and turn dark brown before being scattered by the winds. This maple is one of the most highly ornamental of the smaller trees, and worthy of more general cultivation.

Sugar Maple



(Mich. Trees).

1. Winter twig, x 2.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{1}{2}$.
4. Staminate flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flowering branchlet, x $\frac{1}{2}$.
7. Pistillate flower, enlarged.
8. Fruit, x 1.

ACERACEAE**Sugar Maple. Rock Maple**

Acer saccharum Marsh. [*Acer saccharinum* Wang.]

HABIT.—A stately tree 60-100 feet in height, with a trunk diameter of 3-4 feet; in the open forming stout, upright branches near the ground, in forests making remarkably clean trunks to a good height; the crown is a broad, round-topped dome.

LEAVES.—Opposite, simple, 3-5 inches long and broad; usually 5-lobed (sometimes 3-lobed), the lobes sparingly wavy-toothed, the sinuses broad and rounded at the base; thin and firm; opaque, dark green above, lighter and glabrous beneath, turning yellow and red in autumn; petioles long, slender.

FLOWERS.—April-May, with the leaves; polygamo-monoecious or dioecious; on thread-like, hairy pedicels in nearly sessile corymbs; greenish yellow; calyx campanulate, 5-lobed; corolla 0; stamens 7-8; ovary hairy.

FRUIT.—September-October, germinating the following spring; paired samaras, glabrous, with wings about 1 inch long, diverging slightly.

WINTER-BUDS.—Small, acute, red-brown, glabrous or somewhat pubescent toward the apex, the terminal $\frac{1}{4}$ inch long, the lateral smaller, appressed.

BARK.—Twigs smooth, pale brown, becoming gray and smooth on the branches; old trunks dark gray, deeply furrowed, often cleaving up on one edge in long, thick plates. Plate VII.

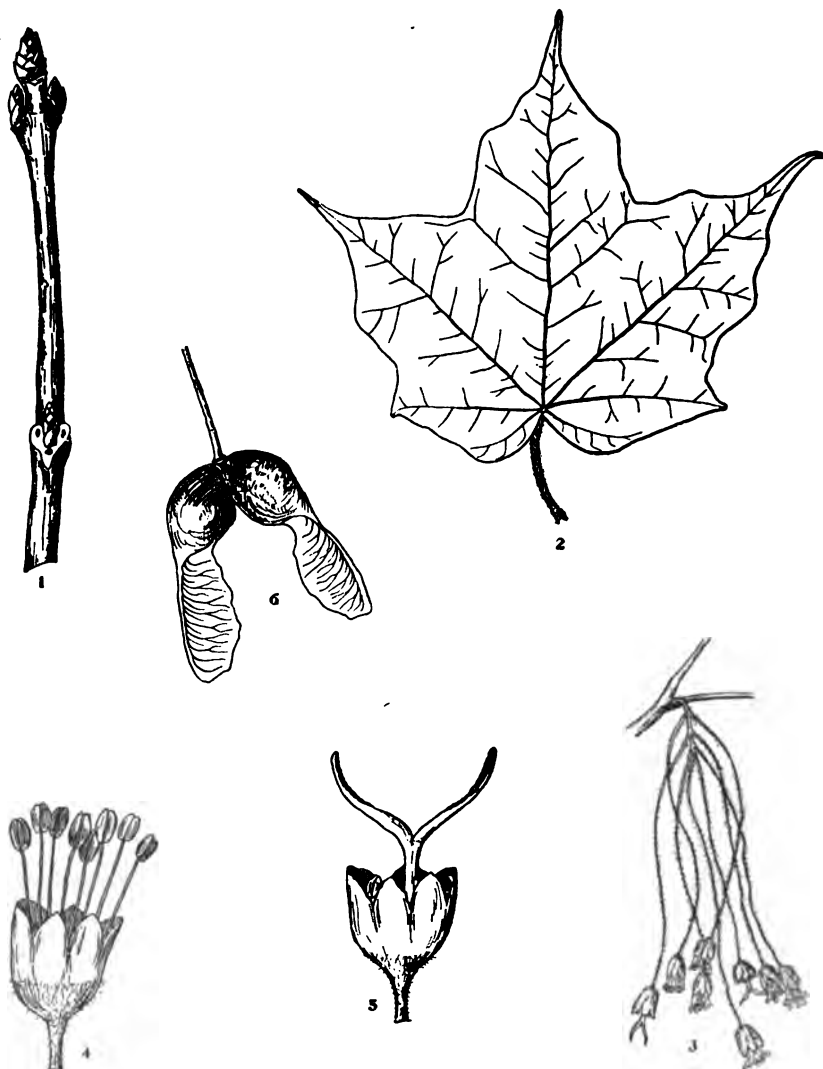
WOOD.—Heavy, hard, strong, close-grained, tough, durable, light brown, with thin, lighter colored sapwood. Page 223.

DISTRIBUTION.—Found throughout Vermont.

HABITAT.—Prefers moist, rich soil in valleys and uplands and moist, rocky slopes.

NOTES.—The sugar maple is everywhere in Vermont, but it thrives best on the cool and rocky uplands. It can be distinguished by its light gray bark which has large, white patches on the younger branches or by its broad, five-lobed leaves which have shallow, rounded, sinuses. In the sugar-bushes of Vermont, trees three and four centuries old not infrequently are found. Besides its value as a sugar tree, its timber is hard and durable. The "curled" and "bird's-eye" maple are unusual forms of this species, produced by a peculiar curling of the fibers.

Black Sugar Maple



(Mich. Trees).

1. Winter twig, x 2.
2. Leaf, x $\frac{1}{2}$.
3. Flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flower, enlarged.
6. Fruit, x 1.

ACERACEAE**Black Sugar Maple**

Acer saccharum nigrum (Michx. f.) Britt. [*Acer nigrum* Michx.]

HABIT.—A stately tree, sometimes reaching a height of 80 feet, with a trunk diameter of 2-3 feet; branches stout, forming a broad, rounded, symmetrical crown.

LEAVES.—Opposite, simple, concave, 5-7 inches across, the breadth usually exceeding the length; usually 5-lobed at maturity, the two lower lobes being small, often reduced to a mere curve in the outline, the pointed lobes undulate or entire and narrowed from the broad, shallow sinuses; thick and firm; glabrous above, downy beneath; petioles stout, usually pendent, tomentose. The sides of the larger leaves often droop giving to the tree an air of depression.

FLOWERS.—May, with the leaves; monoecious; in nearly sessile, umbel-like corymbs; about $\frac{1}{4}$ inch long, yellow, on slender, hairy pedicels 2-3 inches long; calyx campanulate, pilose, 5-lobed; corolla 0; stamens 7-8; ovary hairy.

FRUIT.—Ripens in autumn; glabrous, paired samaras, clustered on drooping pedicels; wings set wide apart, but only slightly diverging.

WINTER-BUDS.—Small, ovoid, acute, with dark red-brown, acute scales, hoary-pubescent on the outer surface.

BARK.—Twigs smooth, pale gray; becoming thick, deeply furrowed and sometimes almost black on the trunk.

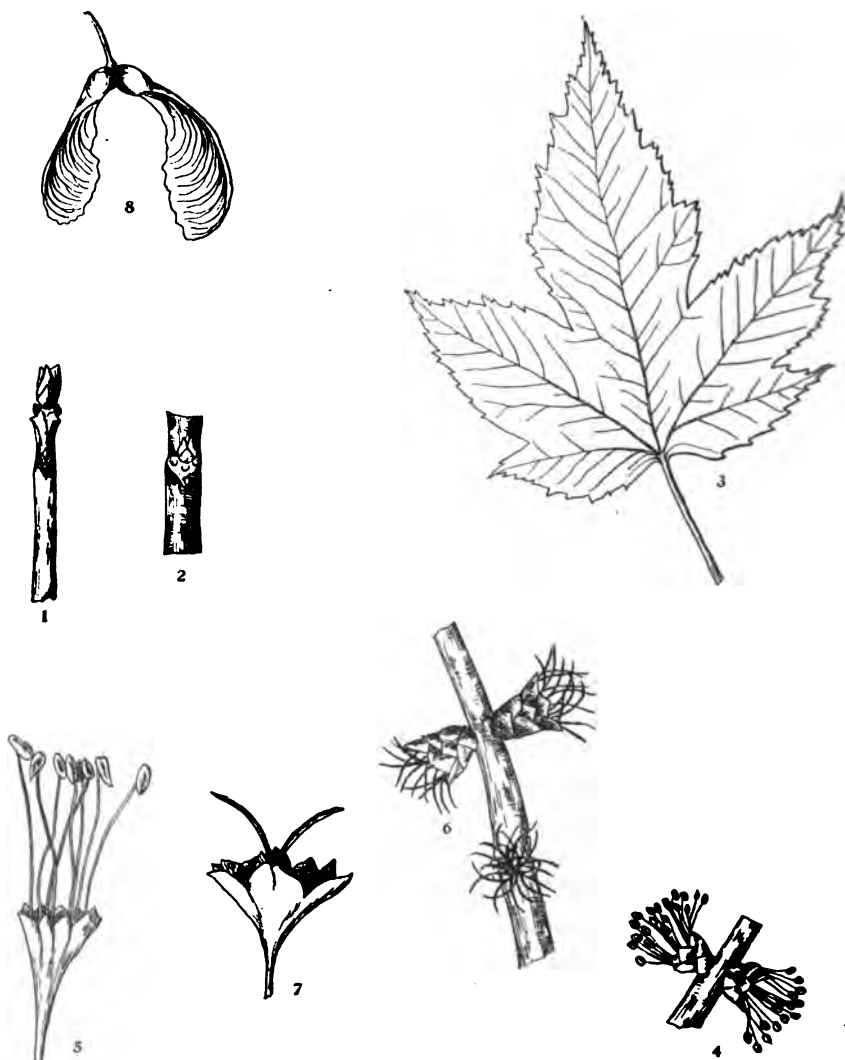
WOOD.—Hard, heavy, strong, close-grained, creamy white, with thin, lighter colored sapwood.

DISTRIBUTION.—Lake Champlain valley. Occasional.

HABITAT.—Low, moist, rich soil of river-bottoms.

NOTES.—This tree has long been a puzzle to botanists. In leaf characters it differs considerably from the sugar maple, but resembles it in fruit characters, general habit and in sugar production. As indicated in the key, the leaf is less deeply lobed, and is minutely hairy on the lower face; it may be hairy also along the leaf stalk. It is thicker and more leathery in texture and usually is heart-shape at the base, the rounded basal lobes sometimes overlapping. This black sugar maple should not be confused with specimens of the ordinary sugar maple having darker bark. Sugar-makers often term such trees "black maples." The bark of this black sugar maple generally is dark, but the leaf characters must be appealed to in its recognition.

White Maple. Silver Maple



(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{1}{2}$.
4. Staminate flowering branchlet, x 1.
5. Staminate flower, enlarged.
6. Pistillate flowering branchlet, x 1.
7. Pistillate flower, enlarged.
8. Fruit, x $\frac{1}{2}$.

ACERACEAE**White Maple. Silver Maple**

***Acer saccharinum* L.** [*Acer dasycarpum* Ehrh.]

HABIT.—A beautiful tree, growing to a height of 60-80 feet, with a trunk diameter of 2-4 feet, usually separating near the ground into 3-4 upright stems which are destitute of branches for a considerable distance. Usually the long, slender branches bend downwards, but with their tips ascending in a graceful curve. Crown broad, especially in its upper portion.

LEAVES.—Opposite, simple, 3-6 inches long and nearly as broad; usually 5-lobed by narrow, acute sinuses which extend nearly to the midrib, the lobes often sublobed, sharply toothed; light green above, silvery white beneath, turning pale yellow in autumn; petioles long, slender, drooping.

FLOWERS.—April-May, before the leaves; polygamo-monoecious or dioecious; small, yellow-green, in crowded, sessile umbels; calyx 5-lobed (sometimes each lobe again divided); corolla 0; stamens 3-7; ovary hairy.

FRUIT.—May, germinating as soon as it reaches the ground; paired samaras, large, glabrous, curving inwards, one samara often aborted.

WINTER-BUDS.—Dark red, blunt; the terminal about $\frac{1}{4}$ inch long, with bud-scales often apiculate; flower-buds clustered on side spurs.

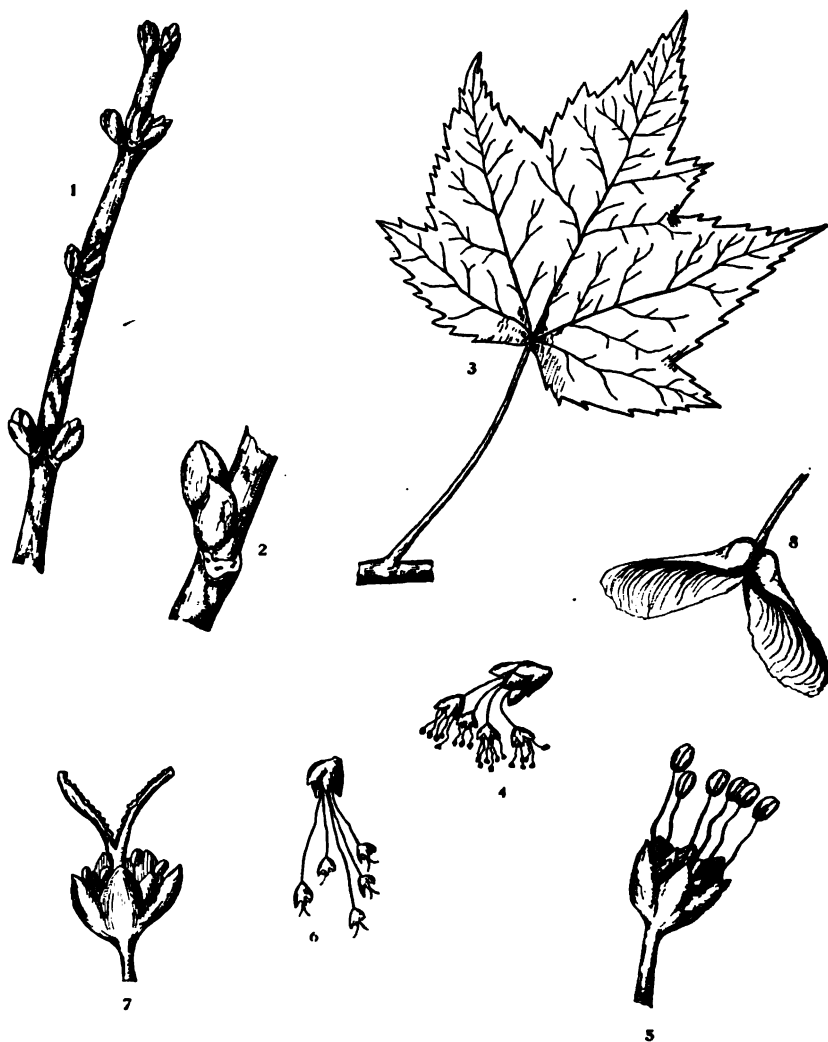
BARK.—Twigs smooth, red-gray, lustrous; young trunks gray, smooth; old trunks dark gray, more or less furrowed, separating into thin, loose scales. Plate VII.

WOOD.—Hard, strong, close-grained, rather brittle, perishable, pale brown, with thick, lighter colored sapwood.

DISTRIBUTION.—Frequent throughout Vermont, especially near the shores of Lake Champlain and tributary streams.

HABITAT.—Prefers low, rich bottom-lands, subject to occasional inundation, but not in swamps; banks of rivers and lakes at low altitudes.

NOTES.—The silver maple is a large, graceful tree, generally distributed along our water courses, especially near the shores of Lake Champlain and the streams emptying into it. It resembles the red maple but is distinguished from it by its longer, more deeply cut, lighter green leaves which are silvery white on the lower side. Although the silver maple flourishes best in moist soil, it will make vigorous growth and become a beautiful shade tree in dry locations.

Red Maple. Swamp Maple

(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x 1.
4. Fascicle of staminate flowers, x 1.
5. Staminate flower, enlarged.
6. Fascicle of pistillate flowers, x 1.
7. Pistillate flower, enlarged.
8. Fruit, x $\frac{3}{4}$.

ACERACEAE**Red Maple. Swamp Maple*****Acer rubrum* L.**

HABIT.—A medium-sized tree 40-50 feet high, occasionally in swamps 60-75 feet; trunks 1-3 feet in diameter; upright branches, which form a low, rather narrow, rounded crown.

LEAVES.—Opposite, simple, 3-4 inches long and nearly as broad; 3-5-lobed by broad, acute sinuses, the lobes irregularly doubly serrate or toothed; glabrous, green above, whitish and generally glabrous beneath, turning bright scarlet in autumn; petioles long, slender.

FLOWERS.—April-May, before the leaves; polygamo-monoecious or dioecious; in few-flowered fascicles on shoots of the previous year, the pistillate red, the staminate orange; sepals 4-5; petals 4-5; stamens 5-8; ovary smooth.

FRUIT.—May-June, germinating immediately after reaching the ground; samaras small, on drooping pedicels 2-4 inches long; wings about 1 inch long, diverging at about a right angle.

WINTER-BUDS.—Dark red, blunt; terminal bud about $\frac{1}{8}$ inch long, with bud-scales rounded at the apex; flower-buds clustered on side spurs.

BARK.—Twigs bright red, lustrous, becoming smooth and light gray on the branches; old trunks dark gray, ridged, separating into plate-like scales. Plate VII.

WOOD.—Heavy, close-grained, not strong, light brown, with thick, lighter colored sapwood.

DISTRIBUTION.—Common throughout Vermont.

HABITAT.—Prefers swamp-lands or banks of streams; moist woods.

NOTES.—The scarlet flowers of this maple give us the brightest spring welcome from the trees. When the red maple is a blaze of color and the other trees are still bare and brown, it is conspicuous and unmistakable, and in autumn the rich coloring of its leaves makes it conspicuous again. The leaves of the silver maple turn yellow and those of the sugar maple yellow or red, but not the crimson or deep red of the red maple. It is distinguished from the sugar maple by its smoother, dark gray bark and by the deeper acute incisions of the leaves although they are subject to much variation. The fruit is about one inch long and like that of silver maple falls in early summer. This tree, common throughout the eastern United States, is very generally distributed in Vermont.

Box Elder

(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{2}$.
3. Staminate flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flowering branchlet, x $\frac{1}{2}$.
6. Pistillate flower, enlarged.
7. Fruit, x 1.

ACERACEAE

Box Elder

Acer negundo L. [Negundo aceroides Moench.]

HABIT.—A sturdy little tree 30-40 feet high, with a trunk diameter of 1-2 feet. Trunk often divides near the ground into several stout, wide-spreading branches, forming a broad, unsymmetrical, open crown.

LEAVES.—Opposite, pinnately compound. Leaflets 3-5 in number, 2-4 inches long, $1\frac{1}{2}$ - $2\frac{1}{2}$ inches broad; ovate or oval; nearly entire, irregularly and remotely coarse-toothed above the middle, or sometimes 3-lobed (often giving the leaflet a jagged outline); apex acute, base variable; glabrous or somewhat pubescent at maturity, with prominent veins. Petioles slender, 2-3 inches long, the enlarged base leaving prominent crescent-shaped scars partly surrounding the winter-buds.

FLOWERS.—April-May, before or with the leaves; dioecious; small, yellow-green; the staminate in clusters on long, thread-like, hairy pedicels; the pistillate in narrow, drooping racemes; calyx hairy, 5-lobed; corolla 0; stamens 4-6; ovary pubescent.

FRUIT.—Early summer, but hanging until late autumn or early spring; narrow, flat, winged samaras, in pairs, clustered in drooping, racemose clusters.

WINTER-BUDS.—Terminal bud $\frac{1}{8}$ - $\frac{1}{4}$ inch long, acute, inclosed in two dull red scales, often hoary or minutely pubescent; lateral buds obtuse, appressed.

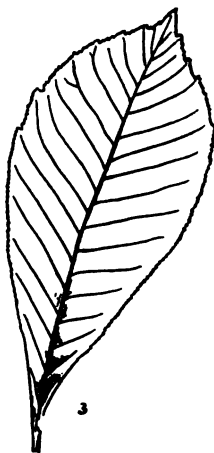
BARK.—Twigs greenish to purple, glaucous; trunk pale gray or light brown, deeply cleft into broad ridges.

WOOD.—Light, soft, close-grained, weak, creamy white, with thick, hardly distinguishable sapwood.

DISTRIBUTION.—From the Winooski river southward, in some places locally abundant; occurs sparingly along streams in the Champlain valley.

HABITAT.—Banks of streams and borders of swamps. Prefers deep, moist soil.

NOTES.—The box elder accommodates itself to almost any situation. It is easily transplanted and grows rapidly. For these reasons it is sometimes planted for shade and ornament, but it is not a desirable tree for this purpose.

Common Horse-chestnut

(Mich. Trees).

1. Winter twig, $\times \frac{3}{4}$.
2. Leaf, $\times \frac{1}{6}$.
3. Leaflet, $\times \frac{1}{2}$.
4. Flower, $\times 1$.
5. Fruit, $\times \frac{1}{2}$.

SAPINDACEAE**Common Horse-chestnut*****Aesculus hippocastanum* L.**

HABIT.—A handsome tree, with a height of 40-60 feet and a trunk diameter of 1-2 feet, forming a broad, conical crown. The regularly occurring branches ascend from the trunk at first, gradually bend downwards as they lengthen, and end in a thick, upturning spray.

LEAVES.—Opposite, digitately compound. Leaflets usually 7, rarely 5, 5-7 inches long, $1\frac{1}{2}$ - $2\frac{1}{2}$ inches broad; obovate, wedge-shaped at the base; irregularly and bluntly serrate; thick; rough, dark green above, paler beneath, turning a rusty yellow in autumn. Petioles long, grooved, swollen at the base.

FLOWERS.—May-June, after the leaves; polygamo-monoecious; large, whitish, in showy, upright, terminal thyrses 8-12 inches long; pedicels jointed, 4-6-flowered; calyx campanulate, 5-lobed; petals 5, white, spotted with yellow and red, clawed; stamens 7, thread-like, longer than the petals.

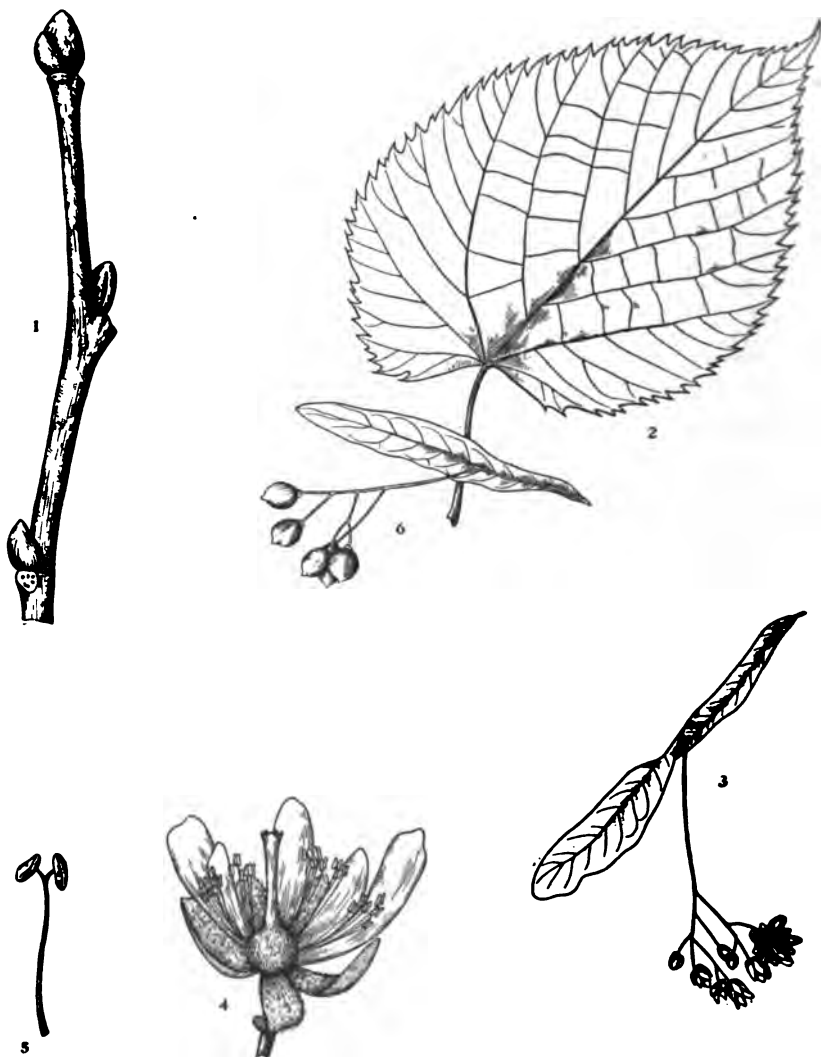
FRUIT.—October; a leathery, globular capsule about 2 inches in diameter, roughened with short spines; containing 1-3 large, smooth, lustrous, brown nuts, marked by large, pale scars.

WINTER-BUDS.—Terminal buds $1-1\frac{1}{2}$ inches long, acute, brownish, covered with glistening, resinous gum; inner scales yellowish, becoming $1\frac{1}{2}$ -2 inches long in spring, remaining until the leaves are nearly half grown.

BARK.—Twigs smooth, red-brown; trunk dark brown and broken into thin plates by shallow fissures; rich in tannin, bitter.

WOOD.—Light, soft, close-grained, weak, whitish, with thin, light brown sapwood.

NOTES.—The horse-chestnut is a native of Greece, but it is extensively cultivated throughout Europe and America, where it is favorite shade tree. A double-flowered variety, *Aesculus hippocastanum*, v. *flöre plèno*, which bears no fruit is a common garden form.

Basswood

(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{2}$.
3. Cyme of flowers, with its bract, x $\frac{1}{2}$.
4. Flower, with two petals, petaloid scales and stamens removed, enlarged.
5. Stamen, enlarged.
6. Fruit, x $\frac{1}{2}$.

TILIACEAE

Basswood

Tilia americana L.

HABIT.—A tree usually 60-70 feet high, with a tall, straight trunk 2-4 feet in diameter; numerous slender branches form a dense, ovoid or rounded crown.

LEAVES.—Alternate, simple, 5-6 inches long, 3-4 inches broad; obliquely heart-shaped; coarsely serrate; thick and firm; glabrous, dull dark green above, paler beneath; petioles slender, 1-2 inches long.

FLOWERS.—June-July, after the leaves; perfect, regular; yellowish white, downy, fragrant; borne on slender pedicels in loose, drooping cymes, the peduncle attached for half its length to a narrow, oblong, yellowish bract; sepals 5, downy; petals 5, creamy white; stamens numerous, in 5 clusters; ovary 5-celled; stigma 5-lobed.

FRUIT.—October; globose, nut-like, woody, gray, tomentose, about the size of peas.

WINTER-BUDS.—Terminal bud absent; lateral buds ovoid, acute, often lopsided, smooth, dark red, $\frac{1}{4}$ inch long.

BARK.—Twigs smooth, reddish gray, becoming dark gray or brown; dark gray and smooth on young stems, on old trunks thick, deeply furrowed into broad, scaly ridges. Plate VII.

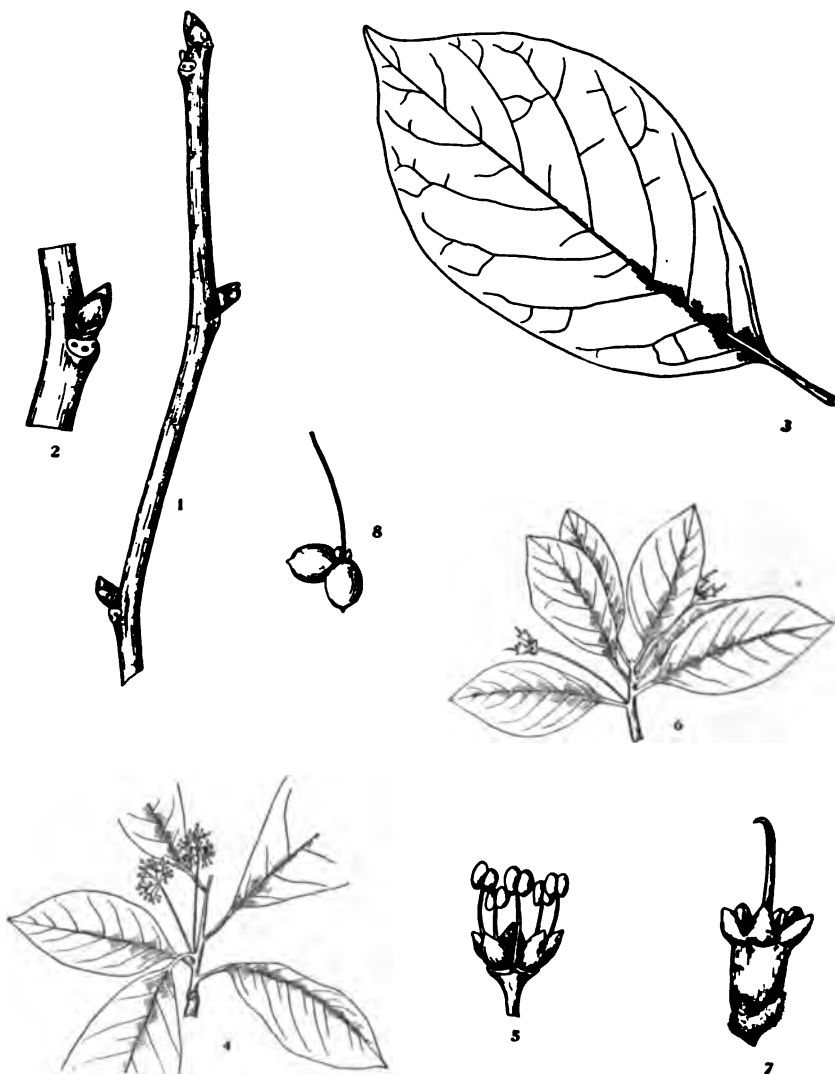
WOOD.—Light, soft, close-grained, tough, light red-brown, with thick sapwood of nearly the same color. Page 231.

DISTRIBUTION.—Common throughout Vermont at altitudes less than 1,000 feet, rare from 1,000-2,000 feet.

HABITAT.—Prefers rich, well-drained, loamy soils.

NOTES.—The basswood is a widely scattered tree in Vermont, growing with the maples, oaks and elms. Its leaves are five or six inches long and nearly as wide, with a base more deeply cordate on one side than the other. The flowers, which open in July, are creamy-white, borne in clusters suspended from a tongue-like leaf or bract. They are very fragrant and so full of nectar that the basswood often is called the bee-tree. The fruit ripens in autumn, forming hard brown balls or nutlets the size of peas. Basswood lumber is brownish or nearly white, light but rather tough, and is extensively used for drawers and similar cabinet work, panels, inside wood-work and for toys. Owing to the fact that it is bent readily, it is used for the bodies and dash boards of carriages and sleighs. The European linden (*T. europea*) occasionally is cultivated. It closely resembles the American species.

Black Gum. Tupelo



(Mich. Trees).

1. Winter twig, x 1.
2. Portion of twig, enlarged.
3. Leaf, x $\frac{3}{4}$.
4. Staminate flowering branchlet, x $\frac{1}{2}$.
5. Staminate flower, enlarged.
6. Pistillate flowering branchlet, x $\frac{1}{2}$.
7. Pistillate flower, enlarged.
8. Fruit, x $\frac{1}{2}$.

CORNACEAE

Black Gum. Tupelo

Nyssa sylvatica Marsh. [*Nyssa multiflora* Wang.]

HABIT.—A medium-sized tree 20-40 feet high, with a trunk diameter of 1-2 feet, forming a rounded to cylindrical crown of slender, spreading, pendulous branches and a stiff, flat spray.

LEAVES.—Alternate, simple, 2-5 inches long, one-half as broad; oblong-obovate to oval; entire, or sometimes wavy-margined; thick and firm; very lustrous and dark green above, pale and often hairy beneath, turning bright scarlet, on the upper surface only, in autumn; petioles short.

FLOWERS.—May-June, with the leaves; polygamo-dioecious; greenish; borne on slender, downy peduncles; the staminate slender-pedicelled, in many-flowered heads; the pistillate sessile, in several-flowered clusters; calyx cup-shaped, 5-toothed; petals 5; stamens 5-10; stigma stout, terete, recurved.

FRUIT.—October; fleshy drupes, ovoid, blue-black, about $\frac{1}{2}$ inch long, sour, in clusters of 1-3.

WINTER-BUDS.— $\frac{1}{8}$ - $\frac{1}{4}$ inch long, ovoid, obtuse, dark red.

BARK.—Twigs greenish or light brown, smooth or often downy, becoming smooth, dark red-brown; thick, red-brown on old trunks, deeply furrowed. Plate VIII.

WOOD.—Heavy, soft, strong, very tough, difficult to split, not durable in contact with the soil, pale yellow, with thick, whitish sapwood.

DISTRIBUTION.—Occasional along the shores of Lake Champlain and in the adjacent river-bottoms; also in southwestern Vermont; has been found in central Vermont as far north as Craftsbury.

HABITAT.—Prefers the borders of swamps and low, wet lands. Rarely flourishes in exposed situations.

NOTES.—The sour gum has a peculiar appearance with horizontal branches and smooth or glossy leaves, borne in beech-like sprays. Its greenish flowers appear in June and are followed by the dark-blue, egg-shaped fruits, one-half of an inch long, with thin, acid flesh, ripening in October. It is of great ornamental value when planted within its range.

THE ASHES

The olive family takes its name from the olive tree of Asia. The only representatives among our native trees are the ashes; but several of the commonly planted ornamental shrubs, the lilacs and other syringas and the beautiful forsythia, belong to this family.

The individual flowers of the ashes are small; but coming as they do before the leaves and appearing in crowded clusters, they are quite conspicuous. The flowers are of two kinds, the pollen producing and the seed bearing being on separate trees. The ashes, like the maples, have prominently winged fruit, but those of the ash hang singly whereas the maple "keys" are always in pairs.

The ashes are among the most useful of the hardwood forest trees of America, yielding to the oaks alone in value. Two species, the black ash and the white ash, occur commonly throughout Vermont, the red ash and the green ash are restricted or local in their distribution. The latter two are very similar and intermediate forms connect them so closely that some authorities rate the green ash as but a variety of the red ash. In using the following key it is to be observed that the ash leaf is compound, that is, each leaf is divided into from seven to eleven smaller leaflets, as will be seen by examining any of the figures.

SUMMER KEY TO THE SPECIES OF FRAXINUS

- a. Lateral leaflets sessile **F. nigra**, p. 193.
- aa. Lateral leaflets petioled.
 - b. Twigs, petioles and lower sides of leaves pubescent,
F. pennsylvanica, p. 189.
 - bb. Twigs, petioles and lower sides of leaves essentially glabrous.
 - c. Lower sides of leaves essentially of the same color as the upper; leaflet-margins rather finely sharp-serrate,
F. pennsylvanica lanceolata, p. 191.
 - cc. Lower sides of leaves paler than the upper; leaflet-margins entire or obscurely serrate **F. americana**, p. 187.

WINTER KEY TO THE SPECIES OF FRAXINUS

- a. Buds rusty-tomentose; twigs more or less downy,
F. pennsylvanica, p. 189.
- aa. Buds not tomentose; twigs not downy.
 - b. Terminal bud black or nearly so, showing 3 pairs of scales in cross-section; bud-scales apiculate at the apex; samaras with broad wings, the seed portion flattish; bark flaky, rubbing off on the hand **F. nigra**, p. 193.
 - bb. Terminal bud brownish, showing 4 pairs of scales in cross-section; bud-scales rounded at the apex; samaras with narrow wings, the seed portion terete; bark ridged, not flaky and rubbing off on the hand.
 - c. Upper margin of leaf-scars deeply concave,
F. americana, p. 187.
 - cc. Upper margin of leaf-scars not concave, but straight across or projecting upward. **F. pennsylvanica lanceolata**, p. 191.

White Ash



(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{4}$.
3. Staminate flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flowering branchlet, x $\frac{1}{2}$.
6. Pistillate flower, enlarged.
7. Fruit, x 1.

OLEACEAE**White Ash*****Fraxinus americana* L.**

HABIT.—A large tree 50-75 feet high, with a trunk diameter of 2-3 feet; forming an open, pyramidal crown of long, slender, lateral branches and a stout, rather sparse spray.

LEAVES.—Opposite, pinnately compound, 8-12 inches long. Leaflets usually 7-9, 3-5 inches long, 1-2 inches broad; short-stalked; ovate to oblong-lanceolate; entire or obscurely serrate; thick and firm; glabrous, dark green above, paler beneath. Petioles glabrous, stout, grooved.

FLOWERS.—May, before the leaves; dioecious; borne in loose panicles on shoots of the previous season; calyx campanulate, 4-lobed; corolla 0; stamens 2, rarely 3; ovary 2-celled.

FRUIT.—August-September, persistent on the branches until mid-winter or the following spring; samaras 1-2 inches long, in crowded, drooping, paniculate clusters 6-8 inches long.

WINTER-BUDS.—Short, rather obtuse; bud-scales apiculate, keeled, 4 pairs, rusty-brown.

BARK.—Twigs at first dark green, becoming gray or light brown, often covered with a glaucous bloom; gray, deeply furrowed into firm, narrow, flattened ridges on the trunk. Plate VIII.

WOOD.—Heavy, hard, strong, close-grained, tough, brown, with thick, lighter colored sapwood. Page 225.

DISTRIBUTION.—Of common occurrence throughout Vermont.

HABITAT.—Prefers a rich, moist, loamy soil, but grows in any well-drained situation; common along stream-beds.

NOTES.—The white ash occurs in all parts of Vermont and upon all kinds of soil, but it prefers a rich, moist location. It is an open spreading tree in the field but in the forest it sends up a clean, straight shaft with a very small head. This character helps to make the white ash one of the valuable timber trees of our forests. The wood is strong, tough, elastic, durable and easily worked. It is manufactured into casings, every kind of furniture, agricultural implements and parts of carriages. It is said that in strength and elasticity the white ash timber from Vermont is superior to that from most other sources. The white oak and the hickories are the only native trees which have a higher value for fuel. This ash is recognized by its compound leaves, nearly twelve inches long, with from seven to nine smooth, petioled leaflets.

Red Ash



(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{3}$.
3. Staminate flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flowering branchlet, x $\frac{1}{2}$.
6. Pistillate flower, enlarged.
7. Fruit, x 1.

OLEACEAE**Red Ash**

Fraxinus pennsylvanica Marsh. [*Fraxinus pubescens* Lam.]

HABIT.—A medium-sized tree 30-50 feet high, with a trunk diameter of 1-2 feet; stout, upright branches and slender branchlets, form a compact, broad, irregular crown.

LEAVES.—Opposite, pinnately compound, 10-12 inches long. Leaflets 7-9, 3-5 inches long, 1-1½ inches broad; short-stalked; oblong-lanceolate to ovate; slightly serrate or entire; thin and firm; glabrous, yellow-green above, pale and silky-downy beneath. Petioles stout, pubescent.

FLOWERS.—May, with the leaves; dioecious; borne in compact, downy panicles on shoots of the previous season; calyx cup-shaped, 4-toothed; corolla 0; stamens 2, rarely 3; ovary 2-celled.

FRUIT.—Early autumn, persistent on the branches throughout the winter; samaras 1-2 inches long, in open, paniculate clusters.

WINTER-BUDS.—Small, rounded; bud-scales rounded on the back, 3 pairs, rusty brown, tomentose.

BARK.—Twigs pale pubescent at first, lasting 2-3 years or often disappearing during the first summer, finally ashy gray or brownish and often covered with a glaucous bloom; brown or dark gray on the trunk, with many longitudinal, shallow furrows; somewhat scaly.

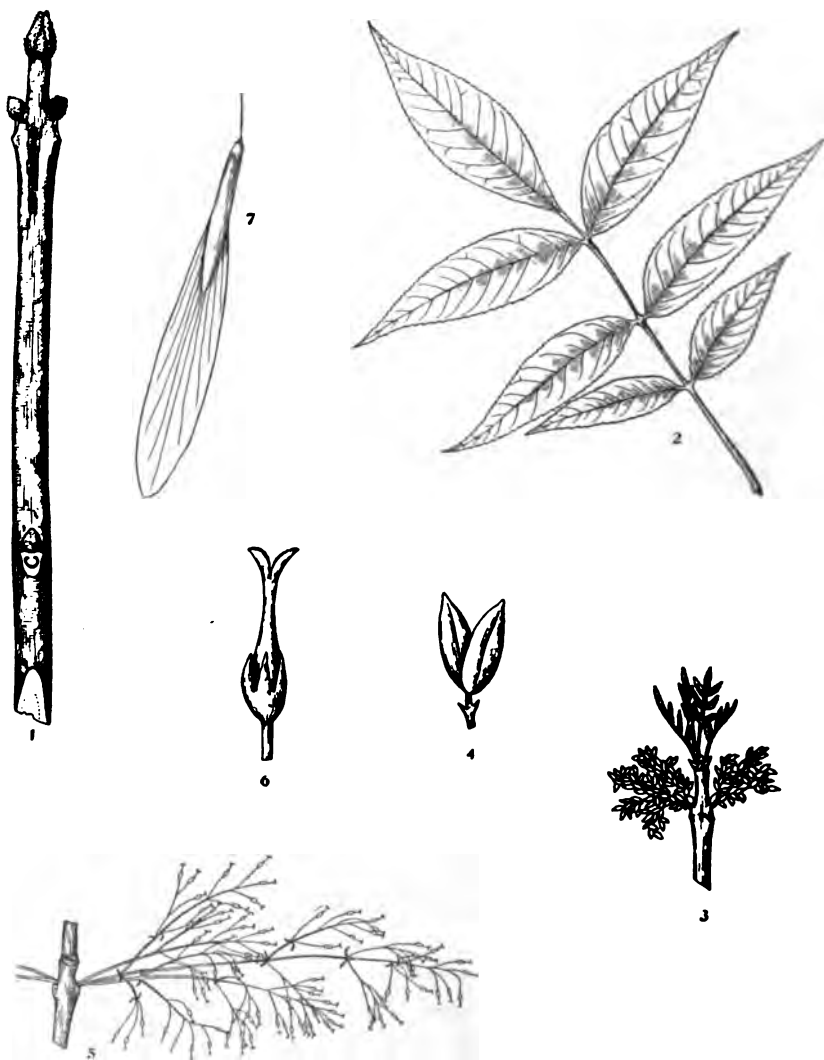
WOOD.—Heavy, hard, strong, brittle, coarse-grained, light brown, with thick, yellow-streaked sapwood.

DISTRIBUTION.—Common along Lake Champlain and its tributaries; occasional in other sections.

HABITAT.—Wet or moist, rich loam; river-banks; swampy lowlands.

NOTES.—The red ash closely resembles the white ash in general appearance. It may be recognized always, however, by looking closely at the buds in winter or at the young shoots or petioles in summer. These parts are velvety with delicate hairs, and it is this characteristic pubescence which suggested the Latin name of the species. The flowers and fruits bear a general resemblance to those of the white ash. The red ash is used considerably in manufactures but is inferior to the preceding species for most purposes. It is distributed generally along the shores of Lake Champlain and its adjacent waters but has not been reported from other parts of Vermont.

Green Ash



(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{3}$.
3. Staminate flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flowering branchlet, x $\frac{1}{2}$.
6. Pistillate flower, enlarged.
7. Fruit, x 1.

OLEACEAE

Green Ash

Fraxinus pennsylvanica lanceolata (Borkh.) Sarg. [Fraxinus lanceolata Borkh.] [Fraxinus viridis Michx. f.]

Considered by some authors to be a distinct species, and by others a variety of *F. pennsylvanica* Marsh., which it resembles. The main points of difference are:

The usual absence of pubescence from the branchlets, the under side of the leaflets, and the petioles.

The rather narrower, shorter, and more sharply serrate leaflets.

The color of the leaves, which is bright green on both sides.

A very hardy tree, of rapid growth and desirable habit, making it useful for ornamental and street planting. Easily transplanted.

The green ash occurs occasionally along the shores of Lake Champlain.

Black Ash

(Mich. Trees).

1. Winter twig, x 1.
2. Leaf, x $\frac{1}{8}$.
3. Staminate flowering branchlet, x $\frac{1}{2}$.
4. Staminate flower, enlarged.
5. Pistillate flowering branchlet, x $\frac{1}{2}$.
6. Pistillate flowers, enlarged.
7. Fruit, x 1.

OLEACEAE

Black Ash

Fraxinus nigra Marsh. [*Fraxinus sambucifolia* Lam.]

HABIT.—A tall tree 60-80 feet high, with a trunk diameter of 1-2 feet; slender, upright branches form in the forest a narrow crown, in the open a rounded, ovoid crown.

LEAVES.—Opposite, pinnately compound, 12-16 inches long. Leaflets 7-11, 3-5 inches long, 1-2 inches broad; sessile, except the terminal; oblong to oblong-lanceolate, long-pointed; remotely, but sharply serrate; thin and firm; dark green above, paler beneath, glabrous. Petioles stout, grooved, glabrous.

FLOWERS.—May, before the leaves; polygamo-dioecious; borne in loose panicles on shoots of the preceding season; calyx 0; corolla 0; stamens 2; ovary 2-celled.

FRUIT.—August-September, falling early, or sometimes hanging on the tree until the following spring; samaras 1-1½ inches long, in open, paniculate clusters 8-10 inches long.

WINTER-BUDS.—Ovoid, pointed; bud-scales rounded on the back, 3 pairs, almost black.

BARK.—Twigs at first dark green, becoming ashy gray or orange, finally dark gray and warted; thin, soft ash-gray and scaly on the trunk. Bark flakes off on rubbing with the hand. Plate VIII.

WOOD.—Heavy, tough, coarse-grained, weak, rather soft, dark brown, with thin, lighter colored sapwood.

DISTRIBUTION.—Common throughout the lower altitudes.

HABITAT.—Deep, cold swamps and low river-banks; wet woods.

NOTES.—The black ash is found in lowlands and swamps. Often it is called the brown ash but this name is confusing as it is applied also to the red ash. This and the white ash are the commoner species of Vermont. They are distinguished easily by the fact that the leaflets of the white ash always are distinctly stalked while the black ash has sessile leaflets. These are seven to eleven in number, often forming a leaf twelve to sixteen inches long which is smooth and green on both sides. Black ash timber is coarser-grained than is that of white ash. It is used for furniture and interior finishings and in the manufacture of baskets.

THE STRUCTURE AND IDENTIFICATION OF OUR COMMON LUMBER WOODS

By C. H. OTIS

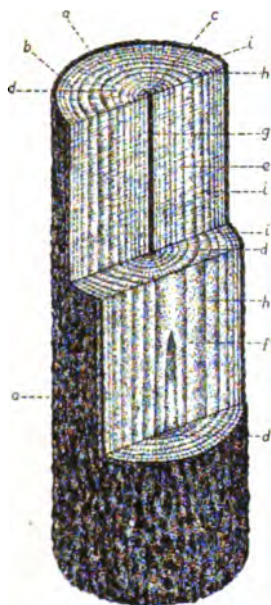
Common as wood is in its varied forms and uses, comparatively few people are able to distinguish our familiar trees when sawed into lumber and fashioned into houses, furniture and other manufactured products. Yet each wood has characteristics of color, odor, graining, weight, hardness, strength and minute structure peculiar to itself which distinguish it from other woods.

The value of each kind of wood for building purposes and every other use is determined to a large extent by its characteristics. These, taken in connection with the available supply of any particular timber in the country, govern the value or cost of that timber in the lumber market. So certain trees, like oak and cedar, because of their durability in contact with the soil, make admirable fence posts; spruce and the broad-leaved white birch and cottonwood possess structural qualities adapting them to the manufacture of paper pulp; hickory, very strong, tough and straight-grained, has long been valued for carriage and wagon stock and tool handles. Many examples might here be cited to show how various woods are peculiarly adapted to certain uses to a greater extent than are others. Again, some species, on account of our wasteful methods of lumbering, failure to provide means of reproduction and lack of restriction as to particular uses, have become so scarce that substitutes are offered in the markets to take their places. To such an extent has this become true that methods are in use to imitate the grain and color of some of the more depleted but valuable woods. Thus birch enters very largely into the composition of a great deal of so-called modern mahogany furniture, and cheap woods are often grained to imitate quarter-sawed white oak.

With the great variety of useful woods to be found in any lumber yard, it is important that consumers of wood in any form should be able to identify the different kinds offered so that they may choose those woods best suited to their particular needs and that they may obtain them and not lumber similar in appearance but otherwise of inferior qualifications.

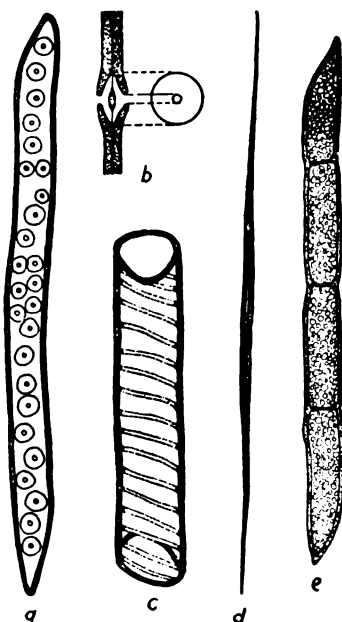
Wood structure and the arrangement of the elements making up the woody tissues constitute the basis of the identification and use of timber. By structure is meant the relative size, shape and form of the

wood elements peculiar to each tree. It is by reason of their structure that some woods are heavier, stronger and stiffer than others, that some are straight- and others are cross-grained, that some are hard and some soft and that some season rapidly and without injury while others have a tendency to check and split. The wide medullary rays of the oak explain the pleasing effect of the wood when quarter-sawed and polished to bring out the grain. The peculiar undulations of the growth



VIII. LOG CUT TO SHOW FEATURES.

- a. Bark.
- b. Sapwood.
- c. Heartwood.
- d. Cross-section.
- e. Radial-section.
- f. Tangential-section.
- g. Pith.
- h. Growth ring.
- i. Medullary ray.



IX. TYPICAL WOOD ELEMENTS, DIAGRAMMATIC. GREATLY ENLARGED.

- a. Tracheid, showing bordered pits.
- b. Scheme of bordered pit in section and surface views.
- c. Segment or single cells of a vessel, showing spiral thickenings.
- d. Wood or bast fiber.
- e. Group of wood-parenchyma cells.

rings sometimes found in the maple produce the "bird's-eye" markings which make the lumber so prized in the manufacture of furniture. It is our purpose to consider briefly the structure of a tree trunk and the various elements of the woody tissues.

If we should go into a forest where felling operations are in progress or into a sawmill where there are unsawed logs, we would have an opportunity to examine the smooth-cut end of a mature log. We would note that it exhibits several well-defined areas or layers.

The first layer on the outside is probably rough externally and dark-colored. This is the bark, (a, fig. VIII), a protective covering to the inner woody tissues. The outer portion of the bark of a forest tree is dead tissue which is stretched and fissured as the tree grows in diameter, while the inner portion is live tissue, serving to conduct food materials up and down the trunk. In some kinds of trees the bark is quite thick, in others very thin. This factor, together with those of color and external appearance, makes the bark, when present, of considerable value in the determination of woods. At the center of the log is a small cylinder of loose tissue less than one-fourth of an inch in diameter, the pith (g, fig. VIII). Lying between the bark and the pith is the wood. In some kinds of trees, like the balsam fir and the hemlock, the wood is all of one color. In others, it consists of two parts distinct from each other in color. The outer portion is called sapwood (b, fig. VIII). It is living tissue and serves chiefly in the living tree to conduct the sap, or water which is taken up by the roots, to the leaves. The width of the sapwood varies with different species and with different individuals of the same species. In very young trees all the wood is sapwood. As the sapwood grows older, the tissue composing it becomes choked so as to prevent the further passage of sap. This tissue then dies and serves only as a support to the rest of the tree, holding up its great weight and making it rigid enough to resist strong winds. It usually becomes darker colored than the sapwood, and is called heartwood (c, fig. VIII). The sapwood and heartwood differ not only in color, but also in durability. In some species only the heartwood is suitable for sawing into lumber, being, as a rule, harder, heavier and drier than sapwood. In other cases where pliability or elasticity is required, as, for example, in hickory and ash which are used in making baskets or for handles of rakes, hoes and golf clubs, the sapwood is more valuable than the heartwood.

Separating the wood from the bark is a very thin layer, the cambium. From this layer is added new wood on the outside of that already formed and new bark on the inside of the old bark. It is by this process that the trunk grows in diameter. Each year the cambium adds a new layer of wood to the circumference of the tree. These layers appear on the end of the log as concentric rings. They are called annual, yearly or growth rings (h, fig. VIII). In maple, birch, white pine and many other woods there is no sharp distinction between the wood formed in the spring and that formed in summer. In other cases the wood which is formed in the spring, when growth is most

rapid, differs in nature from the harder and denser wood formed later in the season. The oaks, elms and hickories present clearly defined layers. The two layers are called early or spring wood and late or summer wood. The presence or absence of well-defined spring and summer wood is an important factor in distinguishing and naming the different woods; in fact, the grain or figure of some kinds of lumber depends entirely upon the difference between spring and summer wood.

Radiating from the center of the trunk toward the bark, like the spokes of a wheel, are slender but more or less distinct lines. These are the medullary rays (i, fig. VIII). Medullary rays serve two functions; they are paths for the conduction of food materials between bark and wood or wood and bark, and they bind the trunk together from pith to bark. Woods differ in the size and number of medullary rays present, the rays being inconspicuous in some and very prominent in others. If an oak log be cut along any of its many radii, i. e., parallel to one of the lines of the medullary rays, the beautiful "flakes" of the quarter-sawed oak are exposed to view. In other trees, like the maples, the medullary rays may be so small as to escape notice. But whether prominent or inconspicuous, the medullary rays help largely to make up the pattern which often readily and surely distinguishes one wood from another.

We have learned from our superficial inspection that a tree is not a simple structure but a complex organism composed of several kinds of tissues, each having its particular function in the life of the tree. In order to continue our study further, it is necessary that we use a hand lens or a compound microscope. If we examine the smoothly cut end of a piece of wood, or, better, a very thin shaving, we find that it is seemingly made up of a network of holes or pores held together by chains of solid tissue, in appearance resembling the chambers of a honeycomb. All trees, all tissues composing trees, are made up of millions of these units, just as a wall is built of bricks and mortar. These units making up the bodies of trees are called cells (fig. IX). A cell may be considered in the nature of a box, but so small is it that it is usually indistinguishable to the naked eye. The walls of the box or cell are composed for the most part of a woody substance called cellulose; we call them cell-walls. In young cells, such as we find in the actively growing parts of trees, the whole cavity of the cell is filled with a slimy substance called protoplasm. The protoplasm is the living substance of the tree; where there is protoplasm, there is life and growth. As the cells grow older and larger, the protoplasm

does not continue to fill the whole cavity within the cell-walls, but forms only a thin lining around the walls. Finally it disappears altogether, leaving the dead cell-walls intact, making the substance called wood. The cells composing wood are not all the same shape or size, but vary greatly according to the function which they serve in the life of the tree. Because of the great variety of the cells composing it, wood takes on various characters of structure, graining and coloring, which are distinctive for each kind of wood and which greatly aid in distinguishing the various kinds from one another.

The wood of conifers is very regular and simple, consisting mainly of cells of one sort. It is this uniformity of structure which makes the wood of conifers valuable for so many purposes. These cells are called tracheids (a, fig. IX). They are vertical, elongated, tapering tubes, one-twentieth to one-fifth of an inch in length, with closed ends and a relatively large cavity. The pointed ends of the tracheids overlap one another in a dovetailed fashion, breaking the joints and making the wood much stronger than it would be otherwise. They are further identified by the presence of pits or pores in their walls which serve as waterways between the tubes. These pits (b, fig. IX) appear as if made up of two circles, and they are for this reason called bordered pits. The other cells making up the wood of conifers are the ray cells. These extend horizontally, and in a radial-section appear as tiers of regular, brick-shaped cells. The cells communicate with one another by numerous pits in the walls. In certain genera the medullary rays are bordered by tracheids similar to the ordinary wood tracheids, but designated as ray tracheids. In one of the pines the ray tracheids have teeth-like projections from the walls, which are useful in identifying this species. Scattered here and there on the cross-section of some coniferous woods are to be seen irregular grayish or brownish dots. These are resin ducts and are especially well-represented in the pines. Resin ducts are openings between cells containing resin, which is manufactured by certain trees. If you cut a limb from a pine tree, the cut surface will very quickly become sticky with the resin which oozes from these ducts. On a warm day in the pine woods the resin is quite apparent by its fragrant odor. Some woods have present also certain cells or groups of cells which produce resin, which gives them a distinctive appearance, and therefore they are called resin cells. Their presence or absence aids in the determination of certain woods.

The wood of broad-leaved trees is much more complex in structure than the wood of conifers. Instead of being made up essentially of

one kind of cells, tracheids, as is the case in the coniferous woods just mentioned, the wood of broad-leaved trees is composed of several kinds of cells. If we examine the cut end of a red oak branch we notice that the spring wood contains many comparatively large openings which are visible even to the naked eye. These openings are called pores; they are cross-sections of open tubes or vessels or tracheae which run up and down the trunk of the tree and out into the branches and twigs. In the beginning they resembled the tracheids of conifers, i. e., they were made up of separate and distinct cells. Later, the end walls of the cells which met endwise were absorbed, leaving a continuous series of connected cells or a tube (c, fig. IX). These tubes or vessels serve in the living tree as water-carriers. For the sidewise conduction of fluids, the vessels are usually abundantly pitted with bordered pits, but the pits are somewhat smaller than those commonly found in the tracheids of coniferous woods. Furthermore, it is very common for vessels, especially the smaller ones, to be marked with spiral thickenings on their interior walls. The scalariform perforations present in the end partitions of the vessels of a few woods, as seen on the radial-section, are sometimes confused with the true spiral thickenings just mentioned. This point may be definitely determined by an inspection of tangential- as well as radial-sections. Tyloses also occur in the vessels of many of the broad-leaved woods, sometimes being visible to the naked eye. Tyloses are usually rather thin-walled cells which protrude into the cavities of the vessels, where they divide rapidly and grow, sometimes filling the entire cavity and plugging the vessels so as to prevent further conduction of fluids. The value of white oak for cooperage is increased by tyloses, which are especially abundant in the vessels of this wood. They are also well-represented in the locust, in this instance being rather thick-walled.

It is convenient to divide broad-leaved woods into two groups, which are characterized by the size and arrangement of the vessels. In some species of wood the vessels which are formed later in the season are much smaller than those formed earlier. A wood of this kind, with its large pores collected into a row or band in each growth ring, is spoken of as ring-porous. In other woods, the pores are more nearly uniform in size in both spring and summer wood. They are designated as diffuse-porous woods. The wood of the maple is of this character. In many of the diffuse-porous woods the pores are too small to be seen with the naked eye, and in some cases they may even be indistinct when viewed with a lens. They should not, however,

because of this, be confused with the non-porous coniferous woods, which they may resemble.

Tracheids in the wood of broad-leaved trees are subordinate elements. They are much smaller and less uniform in size and shape than in conifers and are more abundant in the vicinity of the tubes or vessels. As in conifers, the tracheids bear numerous bordered pits on their walls. In some cases, as in the wood of the ash, tracheids are absent.

Strength, hardness and toughness are given to broad-leaved woods principally by the wood fibers. These are slender, spindle-shaped, sharp-pointed cells with thick walls and narrow cavities (d, fig. IX). Usually they are provided with oblique, slit-like, simple pits. The wood fibers for the most part lie vertically side by side and parallel to one another, but in some woods, like the sycamore, they are more or less interwoven. This makes the wood cross-grained, difficult to work and hard to split.

While the medullary rays of coniferous woods are uniformly small and inconspicuous, they are often broad and prominent in broad-leaved woods. They are largest in the oak, where they may become twenty-five to seventy-five cells wide and several hundred cells high; between these broad rays are numerous smaller ones, mostly uniseriate and from one to twenty cells high. In the sycamore all the rays are broad, while in the beech only a portion of the rays are broad. Ray cells are usually elongated in the radial or horizontal direction and are then termed procumbent. Not infrequently, however, the marginal cells, as in the willow, are elongated vertically; cells of this kind are said to be upright. These differences in the character of the medullary rays are important means of identification.

Another kind of tissue which is more or less prominent in broad-leaved woods is wood parenchyma. Parenchyma consists of vertical groups of short cells, the end ones of each group tapering to a point (e, fig. IX). The cells of parenchyma resemble the cells of the medullary rays; the walls are invariably pitted with rounded, simple pits. The function of the parenchyma is the distribution and storage of the food products manufactured by the leaves. The distribution of parenchyma on the cross-sections of different species is subject to more or less variation, making this feature of considerable importance in classifying woods. Commonly wood parenchyma is grouped around the pores or vessels. In the basswood it occurs in somewhat broken, tangential lines, forming, with the wood fibers, a tier-like arrangement

of the wood elements. In the hickory it forms numerous, fine, concentric lines which are as distinct as the rays. In other woods it may be confined to several rows of cells at the outer limit of the growth ring.

As a final feature having some value in the identification of certain of the woods, is to be mentioned the so-called "pith flecks". They are common in many of our native woods, appearing as crescent-shaped, discolored patches on the cross-section and as brownish streaks running up and down the stem in longitudinal-section. Pith flecks are not a special kind of tissue, but are tunnels made by the larvae of a two-winged insect which lives in the cambium during the growing season. These pith flecks have been found to occur in only five families of trees in the United States, namely, the willow, birch, rose, maple and linden families. They are by no means constant in their occurrence; some stems have numerous pith flecks, while other stems of the same species from the same vicinity do not have them. Taken in conjunction with other characters, however, the presence of pith flecks in considerable numbers may aid in the identification of woods.

The subject of wood structure is one of absorbing interest to one who will but take a little trouble to go beneath the surface. Facts will be revealed which have hitherto lain hidden because of our usual cursory method of handling wood. Some practise may be necessary at first, a little patience may be needed at times, but success will be the reward of honest effort. In all identification work a very sharp knife is necessary. Surfaces must be cut cleanly and smoothly, keeping always in mind that a bruised and broken surface reveals but little of the structure of the wood. Large pieces are not essential, even small cuts along the edge will often suffice. Twigs cut easier than seasoned boards and are frequently as instructive as the more mature wood. Wetting the cut surface will usually make the structural features more prominent. Instructive sections may be made with a very sharp knife or razor, or even with a plane, by cutting very thin pieces and mounting them in water or glycerin between two thin pieces of glass. The sections may even be colored to advantage by soaking them for a time in a dye, thus making certain features more evident. Transparent water colors such as are used in coloring photographs and prints are generally available and will be found to serve as well as the usual laboratory stains. The mounts may be examined with a hand lens by holding them between the eye and the light, or they may be viewed with a compound microscope. If the latter is

employed, the sections of wood must be cut very thin and the customary thin cover-glass must be used between the wood-section and the microscope lens.

In the key to the woods which follows, it will be noticed that two large divisions have been made, one the porous woods, being the great mass of broad leaved woods, the other the non-porous or coniferous woods. Porous woods have again been divided into two groups, the ring-porous woods and the diffuse-porous woods. The key is constructed on the same principles which have been employed throughout in other keys in this bulletin. For an explanation and illustration of the manner of using a key, the reader is referred to the chapter on "Artificial Keys, How Made and Used" (pages 13 to 15). Attention is called to the fact that both naked-eye and microscopic characters have been introduced into the key to the woods. Naked-eye characters are printed in Roman type, the microscopic in italics. While keys based solely upon naked-eye or macroscopic characters have been published, their use often leads the beginner to wrong conclusions or utter confusion. The insertion of microscopic characters may be considered, then, as a necessary affliction which has been imposed to make accurate determinations easy, rather than to complicate the key. The more common or important woods have been illustrated by cross-, radial- and tangential-sections of the woods. In the preparation of these drawings, photomicrographs of very thin, stained sections of typical wood were taken. Blueprints were subsequently made from the negatives and the outlines of the cells were drawn in with India ink. Finally the prints were bleached, the result being a silhouette of the original wood-section drawn accurately to a scale on a white background.

KEY TO THE WOODS OF VERMONT

In the following key, the Roman type calls attention to characters which may readily be distinguished by the naked eye or by the use of a hand lens, and should not be interpreted as indicating more important characters. The italics represent characters that can be studied only with a compound microscope.

The word in parenthesis indicates the section, cross-, radial-, tangential- or longitudinal-, which shows the point in question to greatest advantage.

- a.*¹ Pores (cross) visible and conspicuous, at least with magnifier, i. e., *wood composed of three to six kinds of cells, which are not uniform in structure and usually not arranged in definite radial rows*; resin ducts and resin cells (cross) absent; rays (cross) for the most part conspicuous.
- b.* Growth rings (cross) defined by zones of large pores in the spring wood alternating with the denser summer wood; pores in summer wood small, or few and scattered.
- c.* Rays (cross), or part of them, broad, easily distinguishable by the naked eye at three feet distance; on close inspection, rays of two kinds, broad and fine.
- d.* Pores (cross) abruptly diminishing in size from spring wood to summer wood; *tyloses (longitudinal) present, usually abundant in all large pores.*
- e.* Pores (cross) of spring wood 1-3 rows deep.
- f.* Pores (cross) of summer wood arranged chiefly in single, radial rows, seldom joined tangentially, the rows extending to the periphery of the growth rings,

Quercus bicolor.

- ff.* Pores (cross) of summer wood arranged chiefly in double, radial rows, often joined tangentially, the rows rarely extending to the periphery of the growth rings.
- g.* Radial rows of summer-wood pores (cross) relatively wide; large rays about $\frac{1}{4}$ inch apart,

Quercus macrocarpa.

- gg.* Radial rows of summer-wood pores (cross) relatively narrow; large rays about $\frac{1}{8}$ inch apart,

Quercus alba.

- ee.* Pores (cross) of spring wood 3-5 rows deep.
- f.* Radial rows of small pores (cross) chiefly in several rows, becoming wider toward the periphery of the growth rings; walls of summer-wood pores thin,

Quercus prinus.

¹ *aa.* See page 211.

- ff. Radial rows of small pores (cross), chiefly in one row, becoming narrower toward the periphery of the growth rings; walls of summer-wood pores thick,

Quercus muhlenbergii.

- dd. Pores (cross) gradually diminishing in size from spring wood to summer wood; *tyloses (longitudinal) usually scarce or wanting.*

- e. Wood-parenchyma cells (cross) arranged in concentric lines around the pores; heartwood red-brown,

Quercus velutina.

- ee. Wood-parenchyma cells (cross) grouped irregularly around the pores; heartwood light red,

Quercus rubra, p. 230.

- cc. Pores (cross) all fine, indistinguishable by the naked eye at three feet distance; on close inspection, rays of one kind, all fine.
- d. Pores (cross) of summer wood small and inconspicuous, or when visible single, grouped, or forming short, broken lines, but never forming extended radial or tangential lines.
- e. Rays (cross) clearly distinct to the naked eye at 6-12 inches distance; growth rings for the most part wide to very wide; rays (radial) very high and prominent.
- f. Pores (cross) of late summer wood in large groups of 6-many, joined tangentially by wood parenchyma, often forming tangential lines plainly visible to the naked eye at a distance of 6-12 inches; *tyloses (tangential) very abundant, densely plugging the vessels;* wood yielding a brown stain when rubbed with a wet, white handkerchief.....**Robinia pseudo-acacia.**
- ff. Pores (cross) of late summer wood in small groups of 3-6, not joined tangentially by wood parenchyma, never forming tangential lines which are plainly visible to the naked eye at a distance of 6-12 inches; *tyloses (tangential) only fairly abundant, never plugging the vessels;* wood not yielding a brown stain when rubbed with a wet, white handkerchief.....**Morus rubra.**
- ee. Rays (cross) not clearly distinct to the naked eye at 6-12 inches distance, inconspicuous to microscopic; growth rings (cross) for the most part narrow; rays (radial) not high and prominent.

- f. Pores (cross) of summer wood *solitary, rarely grouped*, not forming short, tangential lines; wood parenchyma (cross) forming more or less continuous, tangential lines as distinct, or nearly so, as the rays; *tyloses (tangential) present* **Carya**, p. 229.
- ff. Pores (cross) of summer wood *usually grouped*, for the most part forming short, tangential lines; wood parenchyma (cross) not forming continuous, tangential lines; *tyloses (tangential) absent*.
- g. Pores (cross) of spring wood 1-2 rows deep, forming a narrow zone not over one-fourth the width of the growth ring. . **Fraxinus, pennsylvanica lanceolata**.
- gg. Pores (cross) of spring wood 3-5 rows deep, forming a broad zone one-third to one-half the width of the growth ring.
- h. Pores (cross) of summer wood *joined by wood parenchyma*, forming short or more or less extended, tangential lines; wood hard and strong.
- i. Lines of pores and wood parenchyma (cross) in summer wood short and broken, mostly near the periphery of the growth ring (*occasionally absent or very indistinct*) . . **Fraxinus americana**, p. 225.
- ii. Lines of pores and wood parenchyma (cross) in summer wood long, more or less extended, usually well distributed through the growth ring..... **Fraxinus pennsylvanica**.
- hh. Pores (cross) of summer wood *not joined by wood parenchyma*, rarely forming tangential lines; wood soft and weak..... **Fraxinus nigra**.
- dd. Pores (cross) of summer wood small, but distinct, grouped or more or less confluent, or joined by wood parenchyma, to form wavy or branching, more or less extended, radial or tangential lines.
- e. Pores (cross) of summer wood arranged in radial, branching lines (when very crowded, radial arrangement somewhat obscured); pores (cross) of spring wood plainly visible to the naked eye at a distance of two feet, *strongly oval or elliptical*, occupying nearly half the growth ring..... **Castanea dentata**.

- ee.* Pores (cross) of summer wood arranged, or joined by wood parenchyma, to form wavy or branching, tangential lines; pores (cross) of spring wood not plainly visible to the naked eye at a distance of two feet, *not strongly oval nor elliptical*, not occupying nearly half the growth ring.
- f.* Lines of summer-wood pores (cross) strongly wavy; *tyloses (tangential) mostly absent, not densely plugging the vessels*; wood not yielding a brown stain when rubbed with a wet, white handkerchief; growth rings (cross) not very wide.
- g.* Pores (cross) of spring wood in 3-many rows; pores (cross) of summer wood small, forming thin, rather broken and disconnected, tangential lines, not strongly wavy; heartwood chocolate-brown,
- Ulmus fulva.***
- gg.* Pores (cross) of spring wood usually in a single row, or nearly so; pores (cross) of summer wood large, forming broad, mostly connected, tangential lines, strongly wavy; heartwood light brown or red.
- h.* Pores (cross) of spring wood large, plainly visible to the naked eye at a distance of 6-9 inches, forming a continuous row; texture coarse; wood hard to split ***Ulmus americana*, p. 225.**
- hh.* Pores (cross) of spring wood small, not visible to the naked eye at a distance of 6-9 inches, not forming a continuous row, but the larger ones few and rather widely separated; texture medium; wood fairly easy to split..... ***Ulmus racemosa.***
- ff.* Lines of summer-wood pores (cross) not strongly wavy; *tyloses (tangential) present, densely plugging the vessels*; wood yielding a brown stain when rubbed with a wet, white handkerchief; growth rings (cross) very wide ***Robinia pseudo-acacia.***
- bb.* Growth rings (cross) not defined by zones of large pores in the spring wood, but pores all the same size, or nearly so, scattered more or less evenly through the growth ring, occasionally more numerous and very often somewhat larger in the spring wood.
- c.* Rays (cross) usually plainly visible to the naked eye at a distance of 6-9 inches.

- d. Rays (cross) uniform, all of them more or less equal in size (see note below¹).
- e. Wood-parenchyma cells (cross) forming continuous or somewhat broken, tangential lines or bands, scarcely visible with a lens; wood light and soft.
- f. Wood elements (cross) alternating with parenchyma elements in a tier-like arrangement; *vessels* (tangential) with spirals; rays (tangential) very narrow, slender-tapering; color light brown to nearly white,
***Tilia americana*, p. 231.**
- ff. Wood elements (cross) not alternating with parenchyma elements in a tier-like arrangement, but confined to 2-4 rows of flattened cells at the outer limit of the growth ring; *vessels* (tangential) without spirals; rays (tangential) rather wide, abruptly-tapering; color bluish to the more common yellow-brown, often striped ***Liriodendron tulipifera*.**
- ee. Wood-parenchyma cells (cross) not forming tangential lines or bands; wood moderately heavy and hard.
- f. Ray cells (radial) about as long as high; *vessels* (longitudinal) plugged at intervals with dark red gum; color rich red-brown or wine.
- g. Rays (cross) distinct to the naked eye; pith flecks (cross) usually absent; pores (cross) large and conspicuous under a hand lens.
- h. Pores (cross) of the spring wood larger and more numerous than those of the summer wood; larger rays (tangential) 3-4-seriate; wood rather soft,
***Prunus nigra*.**
- hh. Pores (cross) of the spring wood not noticeably larger nor more numerous than those of the summer wood; larger rays (tangential) 6-8-seriate; wood rather hard..... ***Prunus serotina*.**
- gg. Rays (cross) barely visible to the naked eye; pith flecks (cross) usually present, often prominent; pores (cross) rather small and inconspicuous, even under a hand lens..... ***Prunus pennsylvanica*.**

¹ The genus *Orataegus* apparently belongs here; but the wood varies so greatly and is of so little importance commercially that no attempt has been made to incorporate it within the key.

ff. Ray cells (*radial*) about twice as long as high; vessels (*longitudinal*) not plugged at intervals with dark red gum; color light brown to reddish.

g. Wood cream-white, without reddish tinge; rays (*radial*) not conspicuously darker than surrounding wood; growth rings (*cross*) usually very wide,

Acer negundo.

gg. Wood light red-brown to decidedly reddish; rays (*radial*) conspicuously darker than surrounding wood; growth rings (*cross*) usually moderately wide to narrow.

h. Larger rays (*tangential*) 4-6-seriate, for the most part broader than the pores (*cross*); pith flecks absent or rare; growth rings more or less distinct; wood very heavy and hard,

Acer saccharum, p. 223

Acer saccharum nigrum.

hh. Larger rays (*tangential*) 2-3-, or occasionally 4-seriate, mostly narrower than the pores (*cross*); pith flecks present, often abundant; growth rings for the most part indistinct; wood rather light and soft.

i. Pores (*cross*) barely visible to the naked eye with close scrutiny; pith flecks (*cross*) usually small, neither abundant nor conspicuous,

Acer saccharinum.

ii. Pores (*cross*) visible to the naked eye with close scrutiny; pith flecks (*cross*) usually rather large, sometimes abundant, more or less conspicuous,

Acer rubrum.

dd. Rays (*cross*) not uniform, some of them conspicuously broad.

e. Rings (*cross*) strongly sinuous; wood white, not showing marked graining on tangential- and radial-sections; broad rays (*cross*) confined to short radii of the concave portions of the rings..... **Carpinus caroliniana.**

ee. Rings (*cross*) regular, not strongly sinuous; wood brownish to reddish, showing marked graining on tangential- and radial-sections; broad rays (*cross*) uniformly distributed, not confined to short radii.

- f. Rays (cross) mostly all broad; *vessels (tangential) with spirals*; rays (*tangential*) between broad rays rarely or never uniseriate; wood cross-grained, difficult to split. **Platanus occidentalis.**
- ff. Rays (cross) only part of them broad; *vessels (tangential) without spirals*; rays (*tangential*) between broad rays mostly uniseriate; wood mostly straight-grained, easy to split. **Fagus grandifolia**, p. 227.
- cc. Rays (cross) mostly not plainly visible to the naked eye at a distance of 6-9 inches, indistinct to microscopic.
- d. Pores (cross), or some of them, plainly visible to the naked eye at a distance of a foot, mostly conspicuous in the spring wood, for this reason often approaching characteristics of ring-porous group; *squarish crystals in cells of wood parenchyma (longitudinal) common.*
- e. Heartwood chocolate-brown, heavy and hard, with mild odor, especially when wet; rays (*tangential*) mostly 2-3-seriate, *thick-tapering*. **Juglans nigra.**
- ee. Heartwood light chestnut-brown, light and soft, odorless, even when wet; rays (*tangential*) mostly uniseriate, *slender-tapering*. **Juglans cinerea.**
- dd. Pores (cross) not visible to the naked eye at a distance of a foot, not conspicuous in the spring wood; *squarish crystals in cells of wood parenchyma (longitudinal) uncommon or wanting.*
- e. *Vessels (tangential) with spirals.* •
- f. Heartwood pale yellow to whitish; rays (*tangential*) all alike, uniseriate throughout, or nearly so,
Aesculus hippocastanum.
- ff. Heartwood brownish, reddish or dark red-brown; rays (*tangential*) not all alike, 1-6-seriate.
- g. Pores (cross) abundant or fairly abundant, rather evenly distributed; growth rings (cross) not sinuous; pith flecks (cross) usually present; wood parenchyma (cross) not forming distinct, tangential markings.
- h. Growth rings narrow; cross-section with curious, sinuous-mottled appearance; sapwood whitish,
Pyrus americana.
- hh. Growth rings rather wide; cross-section without sinuous-mottled appearance; sapwood light brown,
Amelanchier canadensis.

- gg. Pores (cross) not abundant, solitary-scattering or in remote, radial lines; growth rings (cross) sinuous; pith flecks (cross) usually absent; wood parenchyma (cross) forming distinct, tangential markings.

***Ostrya virginiana*.**

ee. *Vessels (tangential) without spirals.*

- f. Rays (tangential) all alike, *uniseriate throughout or nearly so*; wood for the most part soft and light.

- g. Pores (cross) of summer wood markedly smaller and fewer in number than pores of spring wood, arranged in more or less prominent, wavy, concentric lines; wood (radial) without silky luster; *rays (radial) with both upright and procumbent cells*,

***Salix nigra*.**

- gg. Pores (cross) of summer wood not markedly smaller and fewer in number than pores of spring wood, not arranged in more or less prominent, wavy concentric lines; wood (radial) with silky luster; *rays (radial) with only procumbent cells* ***Populus*, p. 229.**

- ff. Rays (tangential) not all alike, but some broad, *1-6-seriate*; wood mostly hard and heavy.

- g. Growth rings (cross) indistinct, very narrow and crowded together; *tyloses (longitudinal) present*; *larger rays (tangential) 1-2-, occasionally 3-seriate*,

***Nyssa sylvatica*.**

- gg. Growth rings (cross) distinct, not very narrow and not crowded together; *tyloses (longitudinal) absent*; *larger rays (tangential) 3-6-seriate*.

- h. Rays (cross) just visible to the naked eye with close scrutiny; pores (cross) more or less uniformly distributed, neither larger nor more numerous in the spring wood; pith flecks (cross) rare or wanting; wood heavy and hard.

- i. *Larger rays (tangential) 3-5-seriate*; pores (cross) visible to the naked eye with close scrutiny ***Betula lenta*.**

- ii. *Larger rays (tangential) 1-2-, sometimes 3-seriate*; pores (cross) hardly visible to the naked eye with close scrutiny. ***Betula lutea*, p. 227.**

hh. Rays (cross) not visible to the naked eye with close scrutiny; pores (cross) not uniformly distributed, but somewhat larger and more numerous in the spring wood; pith flecks (cross) usually rather abundant; wood light and soft.

i. Pores (cross) of spring wood visible to the naked eye with close scrutiny; growth rings (cross) not marked by narrow, whitish, concentric lines; pith flecks (cross) usually small, not conspicuous,

Betula alba papyrifera.

ii. Pores (cross) of spring wood not visible to the naked eye with close scrutiny; growth rings (cross) marked by narrow, whitish, concentric lines, especially near the periphery; pith flecks (cross) usually large, conspicuous,

Betula populifolia.

aa. Pores (cross) not visible nor conspicuous, even with magnifier,
i. e., wood composed mostly of one kind of cells (tracheids), which are uniform in structure and arranged in definite radial rows; resin ducts and resin cells (cross) often present, especially in the summer wood; rays (cross) never conspicuous.

b. Resin ducts or resin cells or both (cross) present, the former usually visible to the naked eye, the latter for the most part prominent and more or less confluent, forming conspicuous tangential lines; fusiform rays (tangential) present (absent in *Juniperus* and *Taxodium*).

c. Resin ducts and resin cells (cross) scattered, single or in groups, but never forming tangential lines; *fusiform rays (tangential) present; rays (radial) with tracheids.*

d. Heartwood distinct in color from sapwood; resin ducts (cross) conspicuous, because of size or color, *the epithelium cells thin-walled; fusiform rays (tangential) broad and prominent, usually with one to several large resin ducts.*

e. Resin ducts (cross) few, widely scattering, *without tyloses; resin cells (cross) present near the outer limit of the summer wood; tracheids (radial) with occasional spirals; heartwood light russet-brown,*

***Larix laricina*, p. 219.**

ee. Resin ducts (cross) numerous, evenly scattered through the rings, *with prominent tyloses; resin cells (cross) wholly absent; tracheids (radial) wholly without spirals; heartwood whitish, orange to reddish.*

- f. Transition (cross) from spring wood to summer wood gradual, the growth rings distinguished by narrow lines of darker colored summer wood; wood soft and light, slightly resinous; *lateral walls of ray cells (radial) of spring wood with 1-2 large pits to each tracheid.*
- g. *Walls of ray tracheids (radial) smooth; pits (radial) on the tangential walls of the summer-wood cells numerous..... Pinus strobus, p. 215.*
- gg. *Walls of ray tracheids (radial) conspicuously toothed; pits (radial) on the tangential walls of the summer-wood cells absent, Pinus resinosa, p. 217.*
- ff. Transition (cross) from spring wood to summer wood more or less abrupt, the growth rings distinguished by broad bands of darker colored summer wood; wood medium hard and heavy, strongly resinous; *lateral walls of ray cells (radial) of spring wood with 2-6 small pits to each tracheid.*
- g. Growth rings (cross) wide, the resin ducts small, widely scattering; *fusiform rays (tangential) having the cells of the inflated portion all or mostly thick-walled, not broken out..... Pinus banksiana.*
- gg. Growth rings (cross) narrow, the resin ducts large, chiefly in the summer wood; *fusiform rays (tangential) having the cells of the inflated portion all or mostly thin-walled, all broken out, Pinus rigida.*
- dd. Heartwood not distinct in color from the sapwood; resin ducts (cross) not conspicuous, of same color as surrounding wood; *fusiform rays (tangential) narrow, not prominent, with only one small resin duct.*
- e. Growth rings (cross) wide; resin ducts (cross) rather numerous, *the epithelium cells thin-walled.*
- f. Resin ducts (cross) scattered through both spring and summer wood, *with tyloses usually absent; pits (radial) on the tangential walls of the summer wood chiefly confined to the outermost tracheid wall,*
Picea canadensis.
- ff. Resin ducts (cross) confined chiefly to the summer wood, *with tyloses present; pits (radial) on the tangential walls of the summer wood not confined to the outermost wall, but usually numerous, Picea mariana.*

ee. Growth rings (cross) narrow; resin ducts (cross) not numerous, *the epithelium cells thick-walled*,

Picea rubra, p. 217.

cc. Resin ducts and resin cells (cross) not scattered, but more or less confluent and forming tangential lines; *fusiform rays (tangential) absent; rays (radial) chiefly or wholly without tracheids*.

d. Wood with odor like cedar oil, especially when wet; heartwood purplish to red-brown, with yellow-white sapwood, its smoothed surface dull; rings (cross) wavy and sinuous,

Juniperus virginiana.

dd. Wood odorless, even when wet; heartwood dull yellow- or gray-brown, differing only in shade from the sapwood, its smoothed surface greasy or waxy; rings (cross) regular, not wavy nor sinuous.....**Taxodium distichum**, p. 223.

bb. Resin ducts (cross) absent and resin cells (cross), if present not prominent, not forming conspicuous, tangential lines; *fusiform rays (tangential) absent*.

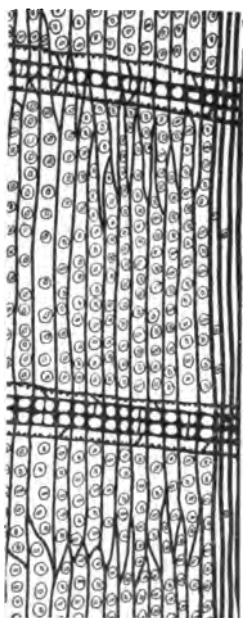
c. Wood with mild odor like cedar oil, especially when wet; heartwood distinct in shade from the sapwood; rings (cross) wavy; wood spongy, difficult to cut smoothly across the grain; *ray tracheids (radial) wholly absent*,

Thuja occidentalis, p. 221.

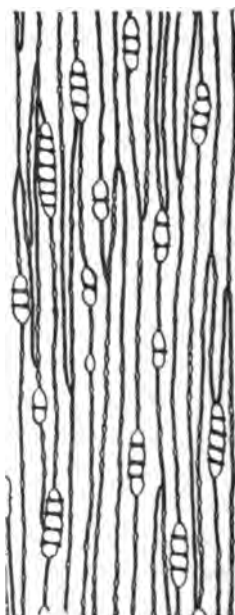
cc. Wood without odor of cedar oil, even when wet; heartwood not distinct in shade from the sapwood; rings (cross) not wavy; wood not spongy, easy to cut smoothly across the grain; *ray tracheids (radial) present*.

d. Transition (cross) from spring wood to summer wood abrupt; wood light red-brown, with rancid odor, especially when wet, cross-grained, splintery and hard to work; resin cells (cross) prominent, but not numerous; *ray tracheids (radial) prominent*.....**Tsuga canadensis**, p. 219.

dd. Transition (cross) from spring wood to summer wood gradual; wood yellow-white to pale brown, odorless, even when wet, straight-grained, not splintery and easy to work; resin cells (cross) absent; *ray tracheids (radial) not prominent, occasional*.....**Abies balsamea**, p. 221.



RADIAL.



TANGENTIAL.



CROSS.

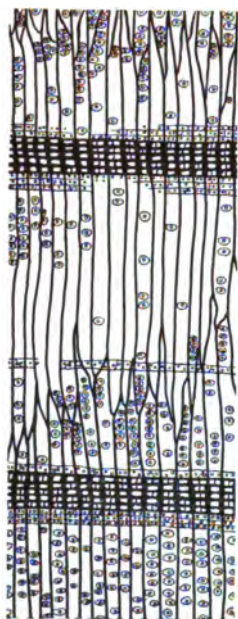
Sections of wood of *Pinus resinosa*, x 101.

Red Pine. Norway Pine***Pinus resinosa* Ait.**

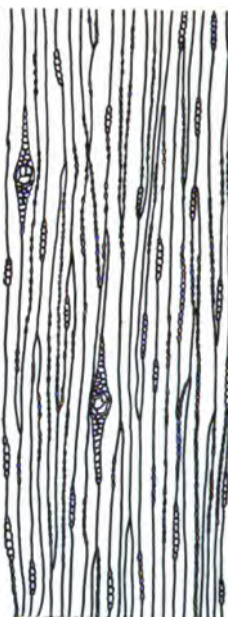
CHARACTERISTICS.—Bark thick, red-brown, shallowly fissured into broad, flat ridges; sapwood thin, yellow to white; heartwood pale red; non-porous; growth rings very wide and distinct; transition from spring wood to summer wood very gradual; rays numerous, faintly distinct, with fusiform rays few and these chiefly rather low and broad; resin ducts numerous, evenly scattered through the rings, with prominent tyloses; resin cells absent; tracheids without spirals.

QUALITIES.—Rather light in weight, 31 pounds per cubic foot, seasoned; fairly soft; moderately strong; shrinkage 3 percent; warps moderately; not durable when exposed; straight- and very close-grained; easily worked; splits readily, but nails well.

USES.—Piles, flooring, sheathing, freight cars, poles, masts, etc.



RADIAL.

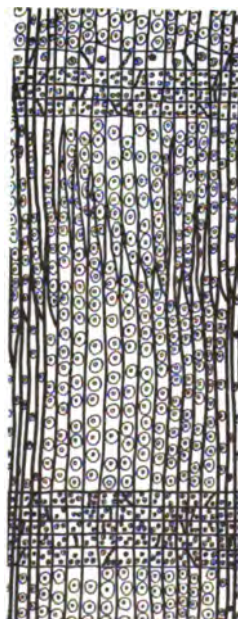


TANGENTIAL.

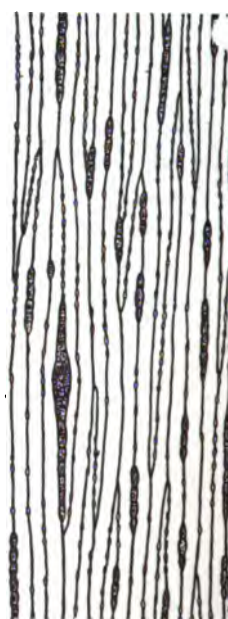


CROSS.

Sections of wood of *Pinus strobus*, x 40.



RADIAL.



TANGENTIAL.



CROSS.

Sections of wood of *Picea rubra*, x 97.

White Pine***Pinus strobus* L.**

CHARACTERISTICS.—Bark thick, dark gray, shallowly fissured into broad, scaly ridges; sapwood thin, whitish; heartwood clear yellow to light brown, turning red on exposure to the atmosphere; non-porous; growth rings wide, distinct; transition from spring wood to summer wood gradual; rays very faint, without resin ducts, the fusiform rays few; resin ducts (vertical) numerous, evenly scattered through the rings, with prominent tyloses; resin cells wholly absent; tracheids entirely without spirals.

QUALITIES.—Very light in weight, 27 pounds per cubic foot, seasoned; very soft; rather weak; shrinkage 3 percent; warps very little; moderately durable when exposed; very close- and straight-grained; easily worked; splits readily, but nails well.

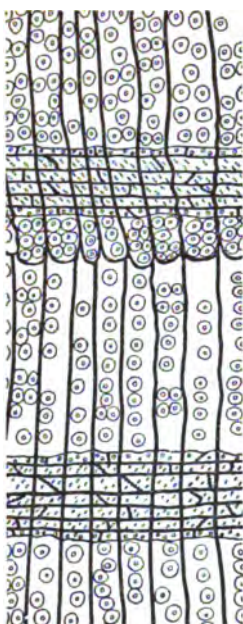
USES.—Doors, window-sashes, interior finish and other carpentry, patterns, cabinet-work, matches, boxes, etc.; the most generally useful of all American woods.

Red Spruce***Picea rubra* (DuRoi) Dietr.**

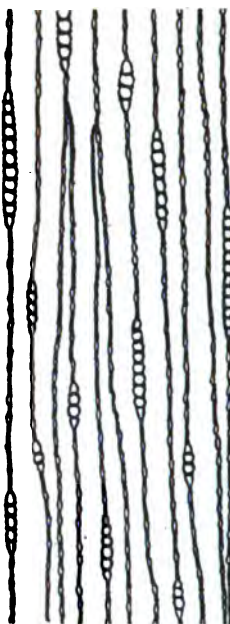
CHARACTERISTICS.—Bark red-brown, with thin, irregular scales; heartwood dull white, with occasional reddish streaks, with sapwood of nearly the same shade; non-porous; growth rings narrow, but distinct; transition from spring wood to summer wood gradual; rays very faint, the fusiform ones narrow; resin ducts few and small, scattered, without tyloses; resin cells absent; tracheids without spirals.

QUALITIES.—Rather light in weight, 28 pounds per cubic foot, seasoned; soft; fairly strong; shrinkage 3 percent; warps little; fairly durable when exposed; straight-grained; easy to plane and tolerably easy to saw, but hard to chisel neatly; splits easily in nailing.

USES.—Boats and canoes, oars and paddles, ship timbers, building construction, silos, sounding boards, paper pulp, ladders, etc.



RADIAL.



TANGENTIAL.



CROSS.

Sections of wood of *Tsuga canadensis*, x 90.



RADIAL.



TANGENTIAL.



CROSS.

Sections of wood of *Larix laricina*, x 65.

Hemlock***Tsuga canadensis* (L.) Carr.**

CHARACTERISTICS.—Bark thick, red-brown or grayish, deeply divided into narrow, rounded, scaly ridges; heartwood light red-brown, ill-smelling, with thin, darker colored sapwood; non-porous; growth rings rather wide, distinct; transition from spring wood to summer wood abrupt; rays numerous, obscure, none of them fusiform; resin ducts absent; resin cells few in number, but prominent; tracheids without spirals.

QUALITIES.—Rather light in weight, 26 pounds per cubic foot, seasoned; soft; fairly strong; shrinkage 3 percent; warps little; checks badly; not durable when exposed; coarse- and crooked-grained; difficult to work, because brittle and splintery; splits easily, but holds nails well.

USES.—Dimension materials, timbers, joints, rafters, plank walks, laths, etc.

Tamarack***Larix laricina* (DuRoi) Koch**

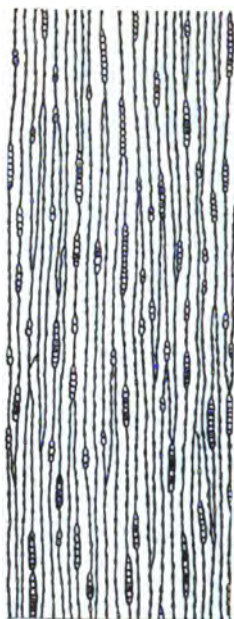
CHARACTERISTICS.—Bark red-brown, scaly, without ridges; sapwood thin, nearly white; heartwood russet-brown; non-porous; growth rings rather broad and uniform, distinct; transition from spring wood to summer wood more or less abrupt; rays inconspicuous, many of them broadly fusiform, prominent and containing resin ducts; resin ducts (vertical) few, widely scattered, without tyloses; resin cells present near outer limit of summer wood; tracheids mostly without spirals.

QUALITIES.—Weight medium, 39 pounds per cubic foot, seasoned; hardness medium; rather strong; shrinkage 3 percent; warps but little; rather coarse-grained; very durable in contact with the soil; easy to work; splits readily.

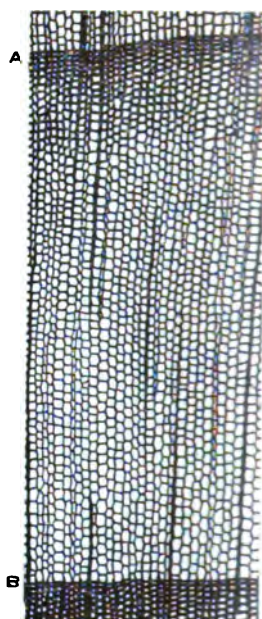
USES.—Ship and boat timbers, telegraph poles, fence posts, railroad ties, etc.



RADIAL.

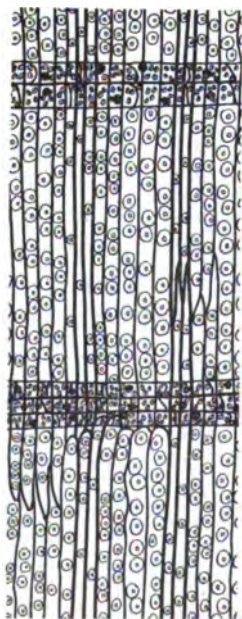


TANGENTIAL.



CROSS.

Sections of wood of *Abies balsamea*, x 44.



RADIAL.



TANGENTIAL.



CROSS.

Sections of wood of *Thuja occidentalis*, x 139.

Balsam Fir***Abies balsamea* (L.) Mill.**

CHARACTERISTICS.—Bark pale gray-brown and marked by swollen resin chambers, or red-brown and roughened by small, scaly plates; sapwood thick, whitish; heartwood yellow-white to pale brown; non-porous; growth rings wide, indistinct; transition from spring wood to summer wood very gradual; rays inconspicuous, never fusiform and mostly without resin ducts; both resin ducts (vertical) and resin cells absent; tracheids without spirals.

QUALITIES.—Very light in weight, 23 pounds per cubic foot, seasoned; very soft; weak; shrinkage moderate; warps little; coarse-grained; perishable in contact with the soil; works easily; splits readily.

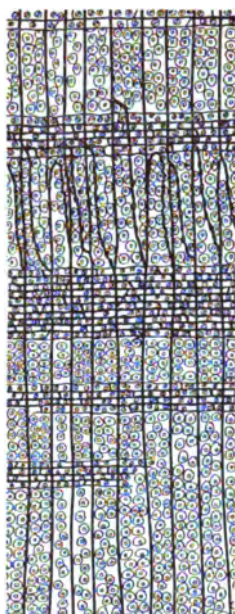
USES.—Cut, sold and used with spruce and pine, boxes, crates, packing cases, sheathing, etc.

Arbor Vitae. White Cedar***Thuja occidentalis* L.**

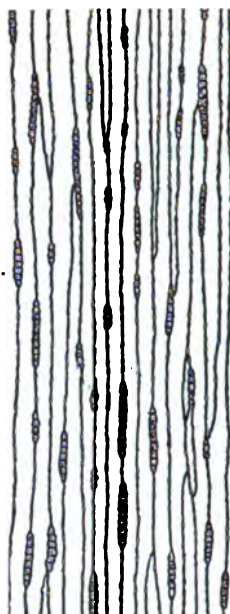
CHARACTERISTICS.—Bark thin, light red-brown, slightly furrowed or deciduous in ragged strips; sapwood thin, whitish; heartwood pale yellow-brown; wood with mild odor like cedar oil; non-porous; growth rings narrow to wide, rather irregular and wavy, fairly distinct by the narrow, but denser summer wood; transition from spring wood to summer wood more or less abrupt; rays very faint, microscopic; resin ducts absent and resin cells few and usually widely scattering; tracheids wholly without spirals.

QUALITIES.—Very light in weight, 19 pounds per cubic foot, seasoned; very soft; very weak; shrinks and checks but little; warps little; rather coarse-grained; brittle; very durable in contact with the soil; easily worked; splits easily, but nails well.

USES.—Posts, railroad ties, shingles, etc.



RADIAL.



TANGENTIAL.



CROSS.

Sections of wood of *Taxodium distichum*, x 47.



RADIAL.



TANGENTIAL.



CROSS.

Sections of wood of *Acer saccharum*, x 127.

Bald Cypress. Cypress¹***Taxodium distichum* (L.) Richard**

CHARACTERISTICS.—Bark light red, shallowly fissured into broad, flat plates and peeling into fibrous strips; sapwood thin, nearly white; heartwood dull yellow- or gray-brown or sometimes blackish; non-porous; growth rings usually very broad and well-marked by the dense and conspicuous summer wood; transition from spring wood to summer wood somewhat gradual; rays very obscure, none of them fusiform; resin ducts absent; resin cells numerous, large, more or less confluent and forming tangential lines on the cross-section; tracheids wholly without spirals.

QUALITIES.—Fairly light in weight, 29 pounds per cubic foot, seasoned; soft; rather weak; shrinkage 3 percent; warps but little, although liable to check; close-grained; very durable in contact with the soil; easy to work; nails well; frequently “peggy” or “pecky” from a fungous disease.

USES.—Shingles, posts, interior finish, boats, cooperage, greenhouse construction, etc.

¹ Not native to Vermont, but included here because of its widespread use.

Sugar Maple. Rock Maple***Acer saccharum* Marsh.**

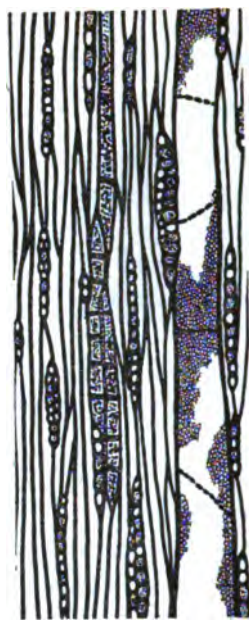
CHARACTERISTICS.—Bark dark gray and deeply furrowed, often cleaving up at one edge in long, thick plates; sapwood thin, lighter colored than the light brown heartwood; diffuse-porous; growth rings narrow, but distinct; pores somewhat uniform in size, not crowded, inconspicuous; rays fine, but distinct; vessels with spirals.

QUALITIES.—Heavy, 43 pounds per cubic foot, seasoned; very hard; very strong; shrinkage 5 percent; warps badly; close-grained, but the fibers sometimes twisted, waved or curly, producing “bird’s eye” and “curly” effects; not durable when exposed; wears evenly; splits badly in nailing; hard to work.

USES.—Flooring, fuel, furniture, wagon-stock, carving, tool-handles, etc.



RADIAL.



TANGENTIAL.



CROSS.

Sections of wood of *Fraxinus americana*, x 92.



RADIAL.



TANGENTIAL.



CROSS.

Sections of wood of *Ulmus americana*, x 138.

White Ash***Fraxinus americana* L.**

CHARACTERISTICS.—Bark gray, deeply furrowed into firm, narrow, flattened ridges; sapwood thick, whitish; heartwood brownish; ring-porous; growth rings rather narrow, distinctly marked by 3-5 rows of large pores in the spring wood; pores of the summer wood small and inconspicuous, joined by wood parenchyma to form short, broken, tangential lines, especially near the periphery of the growth ring; rays inconspicuous to microscopic; vessels without spirals.

QUALITIES.—Fairly heavy, 39 pounds per cubic foot, seasoned; rather hard; fairly strong; shrinkage 5 percent; warps little; straight and close-grained; not durable in contact with the soil; splits readily and nails badly; becomes brittle with age.

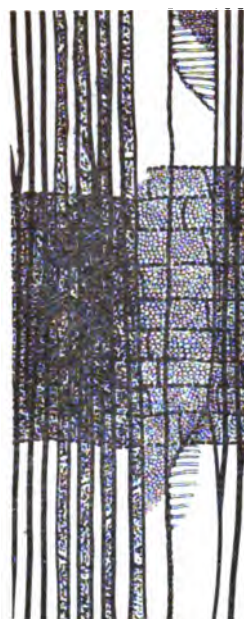
USES.—Farm implements, oars, handles, interior finish, cheap cabinet-work, carriage-stock, etc.

American Elm. White Elm***Ulmus americana* L.**

CHARACTERISTICS.—Bark ash-gray, deeply fissured into broad, scaly ridges; sapwood thick, yellowish; heartwood light brown; ring-porous; growth rings rather wide, distinctly marked by usually one row of large pores in the spring wood; pores of summer wood somewhat smaller, forming broad, mostly connected, tangential lines, which are strongly wavy; rays numerous, inconspicuous; vessels with spirals.

QUALITIES.—Fairly heavy, 34 pounds per cubic foot, seasoned; hardness medium; fairly strong; shrinkage 5 percent; warps and checks considerably; coarse-grained, with the fibers commonly interlaced; not durable in contact with the soil; difficult to split; tough and hard to work.

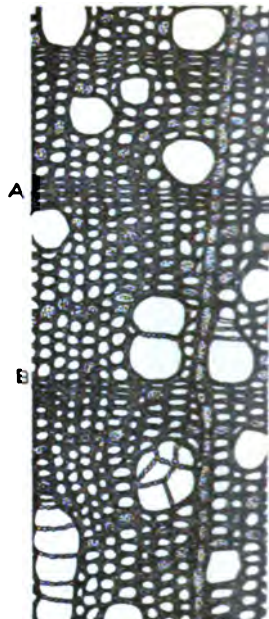
USES.—Wheel-stock, cooperage, heavy timbers, heavy agricultural implements, etc.



RADIAL.



TANGENTIAL.



CROSS.

Sections of wood of *Betula lutea*, x 163.



RADIAL.



TANGENTIAL.



CROSS.

Sections of wood of *Fagus grandifolia*, x 156.

Yellow Birch. Gray Birch***Betula lutea* Michx. f.**

CHARACTERISTICS.—Bark silvery yellow-gray and breaking into strips more or less curled at the edges or blackish and deeply and irregularly fissured into large, thin plates; sapwood thin, whitish; heartwood light brown tinged with red; diffuse-porous; growth rings fairly distinct; pores more or less uniform in size, not crowded, inconspicuous; rays numerous, indistinct; vessels without spirals.

QUALITIES.—Heavy, 40 pounds per cubic foot, seasoned; moderately hard; very strong; shrinkage 6 percent; warps little; close-grained and compact; not durable when exposed; difficult to split and holds nails well; rather hard to work, but polishes well.

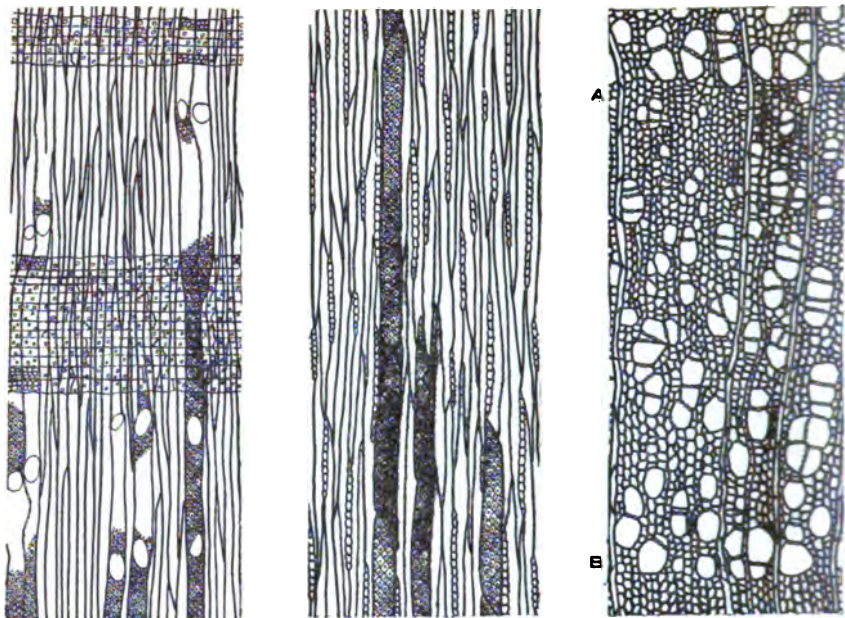
USES.—Furniture, spools, flooring, shoe lasts and pegs, handles, etc.

Beech***Fagus grandifolia* Ehrh.**

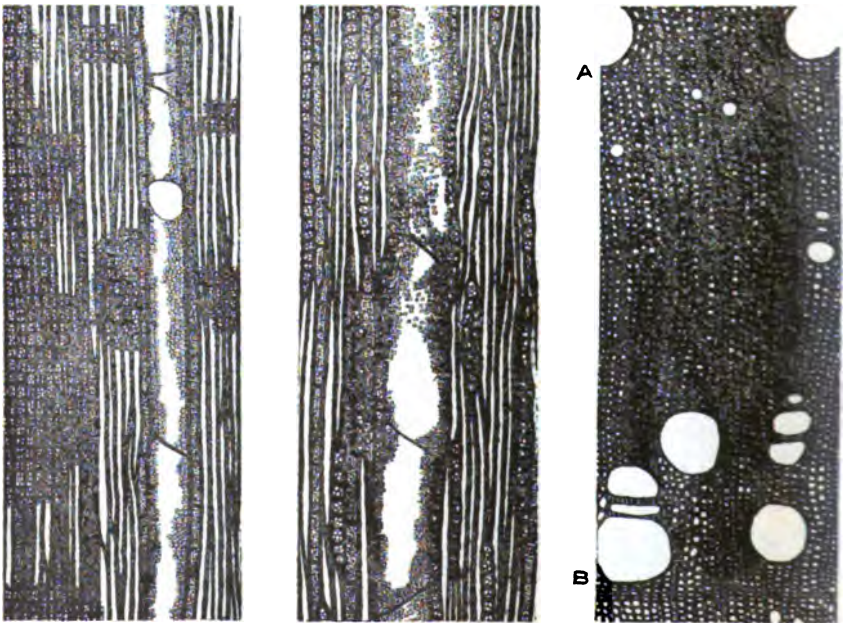
CHARACTERISTICS.—Bark close, smooth, steel-gray, often mottled by darker blotches and bands; sapwood thin, whitish; heartwood light or dark red; diffuse-porous; growth rings obscure; pores largest in spring wood, gradually diminishing in size toward outer limit of summer wood; rays of two kinds, partly very broad and partly very narrow; vessels without spirals.

QUALITIES.—Heavy, 42 pounds per cubic foot, seasoned; rather hard; strong; shrinkage 5 percent; warps and checks during seasoning; straight- and very close-grained; not durable when exposed; moderately difficult to split; tough; hard to work; difficult to nail.

USES.—Ship timbers, flooring, tool-handles, furniture, fuel, etc.



RADIAL. TANGENTIAL. CROSS.
Sections of wood of *Populus tremuloides*, x 80.



RADIAL. TANGENTIAL. CROSS.
Sections of wood of *Carya ovata*, x 100.

American Aspen. Trembling Poplar. Popple***Populus tremuloides* Michx.**

CHARACTERISTICS.—Bark thin, yellowish or greenish and smooth, often roughened with darker, horizontal bands or wart-like excrescences; sapwood thin, whitish; heartwood light brown; diffuse-porous; growth rings very wide, not well-defined; pores more or less uniform in size, but rather more crowded in the spring wood; rays very fine and indistinct; vessels without spirals.

QUALITIES.—Very light, 25 pounds per cubic foot, seasoned; soft; weak; shrinks moderately; warps considerably to excessively, but checks little; close-grained; not durable when exposed; works easily.

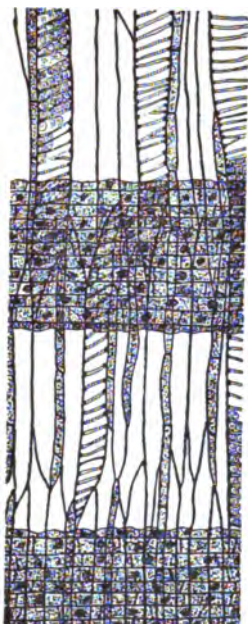
USES.—Paper pulp, boxes, crates, excelsior, woodenware, etc.

Shellbark Hickory***Carya ovata* (Mill.) K. Koch**

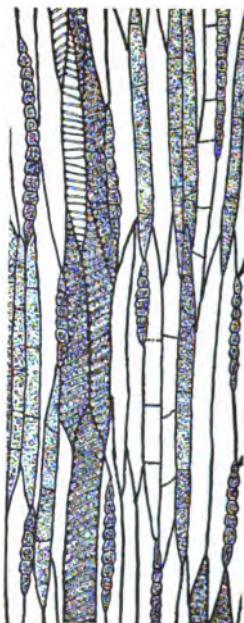
CHARACTERISTICS.—Bark thick and grayish, separating into thick strips 1-3 feet long, free at one or both ends, giving the log a shaggy appearance; sapwood thin, whitish; heartwood light brown; ring-porous; growth rings narrow, but distinctly marked by the one or more rows of relatively large pores in the spring wood; pores of the summer wood small and inconspicuous; rays numerous, but inconspicuous to microscopic; wood parenchyma forming more or less continuous, tangential lines as distinct, or nearly so, as the rays; vessels without spirals, but containing tyloses.

QUALITIES.—Very heavy, 51 pounds per cubic foot, seasoned; very hard; very strong; shrinkage 10 percent; warps badly; straight and close-grained; not durable when exposed; hard to split and very difficult to nail; very tough and hard to work.

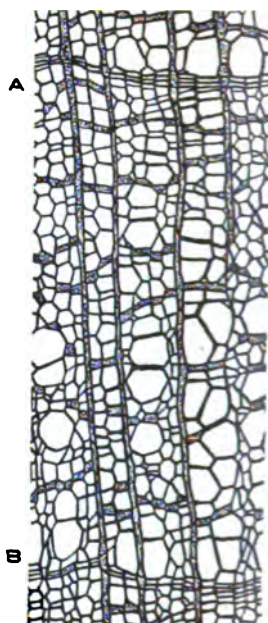
USES.—Agricultural implements, handles, carriage-stock, sled runners, fuel, etc.



RADIAL.



TANGENTIAL.



CROSS.

Sections of wood of *Tilia americana*, x 112.



RADIAL.



TANGENTIAL.



CROSS.

Sections of wood of *Quercus rubra*, x 64.

Basswood***Tilia americana* L.**

CHARACTERISTICS.—Bark thick, dark gray or brownish, deeply furrowed into broad, scaly ridges; inner bark fibrous and tough; sapwood thick, light red-brown, hardly distinguishable from the heartwood; diffuse-porous; growth rings rather narrow, but distinct; pores all the same sizes or nearly so, rather evenly distributed; rays numerous, obscure; wood-parenchyma cells forming continuous or somewhat broken, tangential lines or bands, alternating with wood elements in a tier-like arrangement; vessels with spirals.

QUALITIES.—Light in weight, 28 pounds per cubic foot, seasoned; very soft; very weak; shrinkage 6 percent; very straight- and close-grained; warps comparatively little; not durable in contact with the soil; somewhat tough to split and nails well; very easily worked.

USES.—Carriage and wagon bodies; woodenware, boxes, toys, numerous small articles, etc.

Red Oak***Quercus rubra* L.**

CHARACTERISTICS.—Bark gray-brown, smooth or shallowly fissured into thin, firm, broad ridges; inner bark light red; sapwood thin, darker than the light red-brown heartwood; ring-porous; growth rings rather wide, distinctly marked by several rows of very large pores in the spring wood; pores of summer wood arranged in radial, branching lines, diminishing in size toward outer limits of the summer wood; wood parenchyma grouped irregularly around the pores; rays few, but mostly broad and conspicuous; vessels without spirals.

QUALITIES.—Rather heavy, 45 pounds per cubic foot, seasoned; fairly hard; rather strong; shrinkage 6-10 percent; warps and checks badly; coarse-grained; moderately durable in contact with the soil; splits readily and nails badly.

USES.—Furniture, interior finish, cooperage, agricultural implements, fuel, etc.

A LIST OF VERMONT WOODS ARRANGED IN THE ORDER
OF THEIR WEIGHT FROM HEAVY TO LIGHT

- | | |
|-----------------------------------|---|
| 1. <i>Carya ovata</i> | 20. <i>Betula alba papyrifera</i> |
| 2. <i>Carya alba</i> | 21. <i>Prunus serotina</i> |
| 3. <i>Carya glabra</i> | 22. <i>Platanus occidentalis</i> |
| 4. <i>Betula lenta</i> | 23. <i>Acer saccharinum</i> |
| 5. <i>Quercus alba</i> | 24. <i>Juniperus virginiana</i> |
| 6. <i>Quercus macrocarpa</i> | 25. <i>Pinus resinosa</i> |
| 7. <i>Carpinus caroliniana</i> | 26. <i>Picea mariana</i> , <i>Picea rubra</i> |
| 8. <i>Ulmus racemosa</i> | 27. ¹ <i>Taxodium distichum</i> |
| 9. <i>Quercus velutina</i> | 28. <i>Tilia americana</i> |
| 10. <i>Acer saccharum</i> | 29. <i>Salix nigra</i> |
| 11. <i>Fagus grandifolia</i> | 30. <i>Tsuga canadensis</i> |
| 12. <i>Betula lutea</i> | 31. <i>Liriodendron tulipifera</i> |
| 13. <i>Fraxinus americana</i> | 32. <i>Juglans cinerea</i> |
| 14. <i>Quercus rubra</i> | 33. <i>Picea canadensis</i> |
| 15. <i>Ulmus americana</i> | 34. <i>Pinus strobus</i> |
| 16. <i>Fraxinus nigra</i> | 35. <i>Populus tremuloides</i> |
| 17. <i>Fraxinus pennsylvanica</i> | 36. <i>Abies balsamea</i> |
| 18. <i>Larix laricina</i> | 37. <i>Thuja occidentalis</i> |
| 19. <i>Acer rubrum</i> | |

¹ Not native to Vermont.

GLOSSARY

WITH PAGE REFERENCES TO EXPLANATORY FIGURES

- Abortive.** Defective or barren.
- Achene.** A small, dry, one-seeded fruit in which the ovary wall adheres to the seed.
- Acorn.** The fruit of the oak.
- Acuminate.** Gradually tapering to the apex. Page 7.
- Acute.** Terminating with a sharp angle. Page 7.
- Alternate.** Said of leaves, branches, buds, etc., scattered singly along the stem; not opposite.
- Androgynous.** Composed of both staminate and pistillate flowers.
- Anterior.** The front side of a flower, remote from the axis of inflorescence.
- Anther.** The part of a stamen which bears the pollen. Page 8.
- Apetalous.** Without petals.
- Apex.** The top, as the tip of a bud or the end of a leaf which is opposite the petiole.
- Apiculate.** Ending in a short-pointed tip.
- Appressed.** Lying close and flat against.
- Arborescent.** Attaining the size or character of a tree.
- Aromatic.** Fragrant; with an agreeable odor.
- Axil.** The upper one of the two angles formed by the juncture of a leaf with a stem.
- Axillary.** Situated in an axil.
- Bark.** The outer covering of a trunk or branch. Page 195.
- Bearded.** Bearing a long, bristle-like appendage, or furnished with long or stiff hairs.
- Berry.** A fruit which is fleshy throughout.
- Bipinnate.** Twice pinnate.
- Blade.** The expanded portion of a leaf, etc.
- Bloom.** A powdery or waxy substance easily rubbed off.
- Bract.** A more or less modified leaf subtending a flower or belonging to an inflorescence.
- Branch.** A secondary division of a trunk.
- Branchlet.** A small branch.
- Bud.** An undeveloped stem or branch, with or without scales.
- Bud-scales.** Modified leaves covering a bud.
- Bundle-scars.** Dots on the surface of a leaf-scar, which are scars left by the fibro-vascular bundles which run through the petiole into the blade of the leaf. Page 10.
- Bur.** A spiny fruit.
- Calyx.** The outer part of a perianth, usually green in color. Page 8.
- Cambium.** The ring or zone of tender, growing cells between the bark and the wood.
- Campanulate.** Bell-shaped.
- Capsule.** A dry fruit of more than one carpel which splits at maturity to release the seeds.
- Carpel.** A simple pistil, or one member of a compound pistil.
- Catkin.** A spike of unisexual flowers, each subtended by a bract, and usually deciduous in one piece.
- Cell.** One of the minute units or elements, of very various forms, of which plants are formed. Page 195.
- Cellulose.** The fundamental substance of the cell-wall.
- Chambered.** Said of pith which is interrupted by hollow spaces.
- Ciliate.** Fringed with hairs on the margin.
- Cinereous.** Ash-gray color.
- Claw.** The narrow, stalk-like base of a petal, sepal, etc.
- Cleft.** Cut about half-way to the middle.
- Cluster.** A group of two or more organs (flowers, fruit, etc.) on a plant at a node or end of a stem.
- Columnar.** Having the form of a column.
- Compound.** Composed of two or more similar parts united into a whole.
- Compound leaf,** one divided into separate leaflets.
- Compressed.** Flattened laterally.

- Concentric.** One within another, with a common center.
- Cone.** A fruit with woody, overlapping scales.
- Confluent.** Blended or flowing into one; passing by degrees one into the other.
- Conical.** Cone-shaped, largest at the base and tapering to the apex.
- Conifer.** A tree of the pine family, so called from its bearing cones.
- Coniferous.** Cone-bearing; of, or pertaining to, the pine family.
- Connective.** The portion of a stamen which connects the two cells of the anther.
- Cordate.** Heart-shaped. Page 7.
- Coriaceous.** Leather-like in texture.
- Corky.** Made of, or like cork.
- Corolla.** The inner part of a perianth, usually bright colored. Page 8.
- Corrugated.** Wrinkled or in folds.
- Corymb.** A flower-cluster in which the axis is shortened and the pedicels of the lower flowers lengthened, forming a flat-topped inflorescence, the marginal flowers blooming first. Page 9.
- Corymbose.** Arranged in corymbs.
- Crenate.** Dentate, with the teeth much rounded. Page 8.
- Crenulate.** Finely crenate.
- Cross-grained.** Having the grain gnarled and hard to cut.
- Cross-section.** A section of a body at right angles to its length. Page 195, d.
- Crown.** The upper part of a tree, including the living branches with their foliage.
- Cutting.** A piece of stem, root or leaf which, if cut off and placed in contact with the soil, will form new roots and buds, reproducing the parent plant.
- Cyme.** A broad and flattish inflorescence, the central flowers of which bloom first. Page 9.
- Cymose.** Arranged in cymes.
- Deciduous.** Not persistent; falling away, as the leaves of a tree in autumn.
- Decurrent.** Said of a leaf which extends down the stem below the point of fastening.
- Decussate.** Alternating in pairs at right angles.
- Dehiscient.** Opening by valves or slits.
- Deltoid.** Delta-shaped; triangular.
- Dentate.** Toothed, with the teeth usually pointed and directed outward. Page 8.
- Depressed.** Somewhat flattened from above.
- Dichotomous.** Branching regularly in pairs.
- Diffuse-porous.** Said of wood whose pores are nearly uniform in size and more or less evenly diffused through both spring and summer wood.
- Digitate.** Said of a compound leaf in which the leaflets are borne at the apex of the petiole; finger-shaped.
- Dioecious.** Unisexual, with staminate and pistillate flowers on different individuals.
- Distribution.** The geographical extent and limits of a species.
- Divergent.** Said of buds, cones, etc., which point away from the twig, or of pine needles, etc., which spread apart.
- Dormant.** A term applied to parts which are not in active life.
- Dorsal.** Pertaining to the back or outer surface of an organ.
- Downy.** Covered with fine hairs.
- Drupe.** A fleshy or pulpy fruit in which the inner portion is hard or stony.
- Duct.** See resin duct.
- Ellipsoid.** An elliptical solid.
- Elliptical.** Oval or oblong with regularly rounded ends. Page 7.
- Emarginate.** Notched at the apex. Page 7.
- Entire.** Without divisions, lobes or teeth.
- Epithelium.** The somewhat modified parenchyma lining certain intercellular cavities, as the resin ducts.
- Epithelium cell.** A cell of the epithelium.
- Escape.** Any plant formerly cultivated that grows wild in fields.
- Excrescences.** Warty outgrowths or protuberances.
- Exfoliate.** To cleave off, as of the outer layers of bark.

- Falcate.** Scythe-shaped.
- Fascicle.** A compact cluster of leaves or flowers.
- Fascicled.** Arranged in fascicles.
- Fastigate.** Said of branches which are erect and near together.
- Feather-veined.** Having veins extending from the midrib to the margin, feather-wise.
- Fertile.** Capable of bearing fruit.
- Fertilization.** The mingling of the contents of a male (pollen) and female (ovule) cell.
- Fibro-vascular bundles.** The strands that make up the framework of higher plants.
- Filament.** The part of a stamen which bears the anther. Page 8.
- Filamentose** or **Filamentous.** Composed of threads or filaments.
- Flaky.** With loose scales easily rubbed off (bark).
- Fleshy.** Succulent; juicy.
- Flower.** An axis bearing stamens or pistils or both (calyx and corolla usually accompany these). Page 8.
- Fluted.** With rounded ridges.
- Fruit.** The part of a plant which bears the seed.
- Fungous.** Relating to the *Fungi*, i. e., plant organisms of a lower order destitute of chlorophyll.
- Fusiform.** Thick, but tapering towards each end. *Fusiform ray*, a medullary ray which is fusiform in cross-section.
- Germinate.** To sprout, as of a seed.
- Gibbous.** Swollen on one side.
- Glabrous.** Neither rough, pubescent, nor hairy; smooth.
- Gland.** Secreting surface or structure; a protuberance having the appearance of such an organ.
- Glandular.** Bearing glands.
- Glaucous.** Covered or whitened with a bloom.
- Globose.** Spherical or nearly so.
- Globular.** Nearly globose.
- Graining.** The fibrous arrangement of the particles in wood, determining its hardness, splitting qualities, smoothness, etc.
- Gregarious.** Growing in groups or colonies.
- Growth ring.** An annual ring of growth. Page 195, VIII, h.
- Habit.** The general appearance of a plant, best seen from a distance.
- Habitat.** The place where a plant naturally grows, as in water, clay soil, marsh, etc.
- Hairy.** With long hairs.
- Halberd-shaped.** Like an arrow-head, but with the basal lobes pointing outward nearly at right angles. Page 7.
- Heartwood.** The dead central portion of the trunk or large branch of a tree. Page 195, VIII, c.
- Hirsute.** Covered with rather coarse or stiff hairs.
- Hoary.** Gray-white with a fine, close pubescence.
- Homogeneous.** Uniform; composed of similar parts or elements.
- Hybrid.** A cross between two nearly related species, formed by the action of the pollen of one upon the pistil of the other, yielding an intermediate form.
- Hybridize.** Forming a cross-breed of two species.
- Imbricate.** Overlapping, like the shingles on a roof.
- Indehiscent.** Not opening by valves or slits; remaining persistently closed.
- Indigenous.** Native and original to a region.
- Inflorescence.** The flowering part of a plant, and especially its arrangement.
- Interlaced.** Twisted or linked into each other.
- Internode.** The portion of a stem between two nodes.
- Involucral.** Pertaining to an involucre.
- Involucre.** A circle of bracts surrounding a flower or cluster of flowers.
- Keel.** With a central ridge like the keel of a boat.
- Key-fruit.** An indehiscent winged fruit found in maples and ashes.

Laciniate. Cut into narrow, pointed lobes.

Lanceolate. Lance-shaped, broadest above the base and tapering to the apex, but several times longer than wide. Page 7.

Lateral. Situated on the side of a branch.

Leaf. The green expansions borne by the branches of a tree, consisting of a blade with or without a petiole.

Leaflet. One of the small blades of a compound leaf.

Leaf-scar. The scar left on a twig by the falling of a leaf. Page 10, c.

Legume. A pod-like fruit composed of a solitary carpel and usually splitting open by both sutures (*Leguminosae*).

Lenticels. Corky growths on young bark which admit air to the interior of a twig or branch.

Linear. Long and narrow, with parallel edges (as pine needles). Page 7.

Loam. A non-coherent mixture of sand, clay and organic matter.

Loamy. Of the nature of or like loam.

Lobe. Any division of an organ, especially if rounded.

Lobed. Provided with a lobe or lobes. Page 8.

Luster. Brilliancy or sheen; gloss.

Lustrous. Glossy; shining.

Medullary rays. Plates of cellular tissue radiating from the pith to the bark. They are primary when they extend from pith to bark and secondary when they are of less extent than the primary. Page 195, i.

Membranaceous. Thin and somewhat translucent.

Midrib. The central vein of a leaf or leaflet.

Monocleous. Unisexual, with staminate and pistillate flowers on the same individual.

Mucilaginous. Slimy; resembling or secreting mucilage or gum.

Mucronate. Tipped with a small, abrupt point. Page 7.

Naked. Lacking organs or parts which are normally present in related species or genera.

Naturalized. Said of introduced plants which are reproducing by self-sown seeds.

Nectariferous. Producing nectar.

Node. The place upon a stem which normally bears a leaf or whorl of leaves.

Non-porous. Said of wood whose structure is homogeneous, without large pores.

Nut. A hard and indehiscent, 1-celled, 1-seeded fruit.

Nutlet. A diminutive nut.

Ob lanceolate. Lanceolate, with the broadest part toward the apex. Page 7.

Oblique. Slanting, or with unequal sides.

Oblong. Longer than broad, with sides approximately parallel. Page 7.

Obovate. Ovate, with the broadest part toward the apex. Page 7.

Obovoid. An ovate solid with the broadest part toward the apex.

Obtuse. Blunt or rounded at the apex. Page 7.

Opaque. Dull; neither shining nor translucent.

Opposite. Said of leaves, branches, buds, etc., on opposite sides of a stem at a node.

Orbicular. Circular. Page 7.

Oval. Broadly elliptical. Page 7.

Ovary. The part of a pistil that contains the ovules. Page 8.

Ovate. Egg-shaped, with the broad end basal. Page 7.

Ovoid. Solid ovate or solid oval.

Ovule. The part of a flower which after fertilization becomes the seed.

Palmate. Radiately lobed or divided; hand-shaped.

Panicle. A loose, irregularly compound inflorescence with pedicellate flowers. Page 9.

Panicle. Arranged in panicles or resembling a panicle.

Papilionaceous. Butterfly-like, as in flowers of the *Leguminosae*.

Parenchyma. The soft, thin-walled, cellular tissue of plants. Page 195, IX, e.

Parenchyma elements. The cells or units composing the parenchyma.

Pedice. The stalk of a single flower in a compound inflorescence.

Pedicellate. Borne on a pedicel.

Peduncle. A primary flower-stalk, supporting either a cluster or a solitary flower.

Pendent. Hanging downward.

Pendulous. More or less hanging or declined.

Perfect. Said of a flower with both stamens and pistil. Page 8.

Perianth. The calyx and corolla of a flower considered as a whole.

Periphery. Circumference.

Persistent. Long-continuous, as leaves through the winter, calyx on the fruit, etc.

Petal. One of the divisions of a corolla. Page 8.

Petiolate. Having a petiole.

Petiole. The stem or stalk of a leaf.

Petiolulate. Having a petiolule.

Petiolule. The stem or stalk of a leaflet.

Pilose. Hairy with long, soft hairs.

Pinnate. Compound, with the leaflets arranged along both sides of a common petiole.

Pistil. The seed-bearing organ of a flower, normally consisting of ovary, style and stigma. Page 8.

Pistillate. Provided with a pistil, but usually without stamens.

Pit. A small hollow or depression, as in a cell-wall. Page 195, IX, a.

Pith. The softer central part of a twig or stem. Page 195, VIII, g.

Pith flecks. Dark marks in timber due to the cavities made by the larvae of certain insects working in the cambium.

Pod. A dry and many-seeded, dehiscent fruit.

Pollen. The fecundating grains borne in the anther.

Polygamo-dioecious. Sometimes perfect, sometimes unisexual, both forms borne on different individuals.

Polygamo-monoecious. Sometimes perfect, sometimes unisexual, both forms borne on the same individual.

Polygamous. Sometimes perfect, sometimes unisexual, both forms borne on the same or on different individuals.

Pome. A fleshy fruit, as the apple.

Pore. Any small aperture; a name given to the large vessels or tracheids in hard woods.

Porous. Having large pores visible to the naked eye. See ring-porous and diffuse-porous.

Posterior. The back side of a flower, next to the axis of inflorescence.

Prickle. A small spine growing from the bark.

Procumbent. Lying flat, with the long axis in a horizontal direction.

Protoplasm. The living matter of cells, into which all nourishment is taken and from which all parts are formed.

Puberulent. Minutely pubescent.

Puberulous. Minutely pubescent.

Pubescence. A covering of short, soft hairs.

Pubescent. Covered with short, soft hairs.

Punctate. Dotted with translucent or colored dots or pits.

Raceme. A simple inflorescence of flowers on pedicels of equal length arranged on a common, elongated axis (rachis). Page 9.

Racemose. Resembling a raceme.

Rachis. The central axis of a spike or raceme of flowers or of a compound leaf.

Radial. Radiating, as from a center, i. e., as from the pith.

Radial-section. A longitudinal-section of a body which passes through its center, as the pith of a twig or log. Page 195, VIII, e.

Ray. I. e., medullary ray.

Ray cell. A cell of the medullary ray.

Ray tracheid. A tracheid found in the medullary rays of some trees.

Recurved. Curved downward or backward.

Resin cell. A cell which secretes resin.

Resin duct. A canal or opening between cells containing fluid resin.

Reticulate. Netted.

Rhombic. Equilateral, with the angles oblique.

Ring. Meaning growth ring.

- Ring-porous.** Said of wood whose large pores are collected into a row or band in each growth ring.
- Rough.** Harsh to the touch; pubescent.
- Rugose.** Wrinkled.
- Samara.** An indehiscent winged fruit.
- Sapwood.** The living outer portion of a trunk or large branch of a tree between the heartwood and the bark. Page 195, VIII, b.
- Scalariform.** Having markings suggestive of a ladder.
- Scales.** Small modified leaves, usually thin and scarious, seen in buds and cones; the flakes into which the outer bark often divides.
- Scaly.** Provided with scales.
- Scar.** See leaf-scar.
- Scarious.** Thin, dry, membranaceous; not green.
- Scurfy.** Covered with small bran-like scales.
- Seed.** The ripened ovule.
- Sepal.** One of the divisions of a calyx. Page 8.
- Seriate.** Disposed in series or rows.
- Serrate.** Toothed, the teeth sharp and pointing forward. Page 8.
- Sessile.** Without a stalk.
- Sheath.** A thin enveloping part as of a leaf, any body enwrapping a stem.
- Shrinkage.** A contraction of any material, as wood, into less bulk or dimensions.
- Shrub.** A bushy, woody growth, usually branched at or near the base, less than 15 feet in height.
- Silhouette.** A drawing having its outline filled in with uniform color, commonly black.
- Simple.** Of one piece; not compound.
- Sinuate.** Strongly wavy. Page 8.
- Sinuuous.** In form like the path of a snake.
- Sinus.** The cleft or space between two lobes.
- Smooth.** Smooth to the touch; not pubescent.
- Spatulate.** Wide and rounded at the apex, but gradually narrowed downward. Page 7.
- Sphagnous.** Resembling or allied to the genus *Sphagnum*, a moss.
- Spike.** A simple inflorescence of sessile flowers arranged on a common, elongated axis (rachis). Page 9.
- Spine.** A sharp woody outgrowth from a stem.
- Spirally.** As though wound in a spiral around an axis.
- Spirals.** A term applied to the spiral thickenings of tracheids and vessels. Page 195, IX, c.
- Spontaneous.** Self-planted or generated; wild or sporadic; growing without human agency.
- Spray.** The aggregate of smaller branches and branchlets.
- Spring wood.** The wood produced early in the growing season, characterized by larger ducts and cells and thinner walls than the later growths possess; the inner portion of each annual increment.
- Spur.** A hollow sac-like or tubular extension of some part of a blossom.
- Stamen.** The pollen-bearing organ of a flower, normally consisting of filament and anther. Page 8.
- Staminate.** Provided with stamens, but usually without pistils.
- Staminodium.** A sterile stamen.
- Sterile.** Unproductive, as a flower without pistil, or a stamen without anther.
- Stigma.** The part of a pistil which receives the pollen. Page 8.
- Stipules.** Leaf-like appendages on either side of a leaf at the base of the petiole.
- Stipule-scar.** The scar left by the fall of a stipule. Page 10.
- Striate.** Marked with fine longitudinal stripes or ridges.
- Strobile.** A cone.
- Style.** The part of a pistil connecting ovary with stigma. Page 8.
- Sub.** A prefix applied to many botanical terms, indicating somewhat or slightly.
- Subtend.** To lie under or opposite to.
- Sucker.** A shoot arising from a subterranean part of a plant.

Summer wood. The wood produced late in the growing season, characterized by smaller ducts and cells and thicker walls than the earlier growths possess; the outer portion of each annual increment.

Superposed. Placed above, as one bud above another at a node.

Suture. A junction or line of dehiscence.

Tangential. At right angles to the medullary rays.

Tangentially. In a tangential manner.

Tangential-section. A longitudinal-section of a body at right angles to any one of its radii; any longitudinal-section of a tree trunk which does not pass through the pith. Page 195, VIII, f.

Terete. Circular in cross-section.

Terminal. Situated at the end of a branch.

Ternate. In threes.

Tetrahedral. Having, or made up of, four faces (triangles).

Texture. The disposition, arrangement or character presented by the different elements in the structure of the wood.

Thorn. A stiff, woody, sharp-pointed projection.

Thyrse. A contracted or ovoid and usually compact panicle.

Tissue. The texture or material built up by the union of cells of similar origin and character.

Tolerant. Capable of enduring more or less heavy shade.

Tomentose. Densely pubescent with matted wool.

Toothed. With teeth or short projections.

Torus. The part of the axis of a flower which bears the floral organs.

Trachea. A duct or vessel. Page 195, IX, b.

Tracheid. A long, slender cell, with closed ends and its walls thickened after the cell has attained its full size. Page 195, IX, a.

Transition. Change as from spring wood to summer wood.

Transverse. Said of a wood section made at right angles with the axis of the stem; across the grain.

Tree. Usually defined as a plant with a woody stem, unbranched at or near the base, reaching a height of at least 15 feet.

Trunk. The main stem of a tree.

Turbinate. Top-shaped.

Tylosis. A growth, frequently exhibiting repeated cell-division, intruding within the cavity of a duct or vessel from the wall of a contiguous growing cell.

Umbel. A simple inflorescence of flowers on pedicels which radiate from the same point. Page 9.

Umbellate. Arranged in umbels.

Undulate. With a wavy margin or surface. Page 8.

Uniseriate. In one horizontal row or series.

Unisexual. Of one sex, either staminate or pistillate; not perfect.

Veins. Threads of fibro-vascular tissue in a leaf, petal, or other flat organ.

Vessel. A duct or jointed tube which becomes continuous by the more or less complete absorption of the intervening cross-walls. Page 195, IX, b.

Villose or Villous. Covered with long, soft hairs.

Viscid. Glutinous; sticky.

Warp. To become uneven in outline, as by shrinkage; to become twisted or distorted out of shape.

Whorl. An arrangement of leaves or branches in a circle round an axis.

Wing. Any membranous or thin expansion bordering or surrounding an organ.

Wood. The hard part of a stem lying between the pith and the bark.

Wood elements. The cells or units making up the wood.

Wood fibers. Long, slender cells with thick walls and narrow cavities, which impart strength and toughness to the wood and bark. Page 195, IX, d.

Wood parenchyma. A several-celled fiber in which the end cells have pointed extremities while the intermediate cells have square ends. Page 195, IX, e.

Woolly. Covered with long and matted or tangled hairs.

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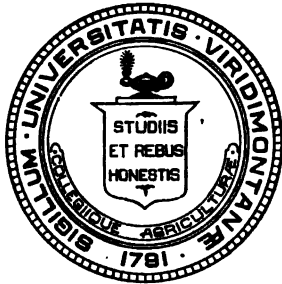
Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

STUDIES OF THE VALUES OF DIFFERENT
GRADES OF MILK IN INFANT FEEDING

by

R. M. WASHBURN and C. H. JONES



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BULLETIN 195: STUDIES OF THE VALUES OF DIFFERENT GRADES OF MILK IN INFANT FEEDING

By R. M. WASHBURN, (FORMERLY) ANIMAL AND DAIRY HUSBAND-
MAN AND C. H. JONES, CHEMIST¹

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¹Considerable work was done during 1907 by the former animal and dairy husbandman, C. L. Beach, the results of which are incorporated in part in the matter in sections IV and VII.

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SUMMARY

The answer to seven questions was sought in the course of the experimental trials. These questions, together with the answers, concisely stated, are as follows:

1. What fat grade of milk is best adapted to the growth and well being of young animals?

A milk with a nutritive ratio of about 1 : 3 with a relatively low fat content. (See conclusions, pages 46-47).

2. Is a milk the fat globules of which are relatively small on that account preferable in the feeding of young animals to a milk the fat globules of which are relatively large?

The size of the fat globules has no practical bearing on the relative values of milks in infant feeding. The alleged superiority of Holstein milk, if really existent, seems more likely to be due to its low fat content than to the size of its fat globules. (See conclusions, pages 54-55).

3. Does the process of homogenization improve milk as a food for young animals?

The homogenization of the fat does not seem to be helpful, but the casein of the milk is sufficiently modified by the application of this process so that possible benefit may result from its employment. (See conclusions, pages 68-69).

4. Are condensed (sweetened) or evaporated (unsweetened) milks as well adapted to infant feeding as is normal cows' milk?

Evaporated (unsweetened) milk compared favorably with normal, whole, standardized milk, but the sweetened condensed milk proved a thoroughly undesirable food, producing a dangerously fat body. (See conclusions, pages 79-80).

5. To what extent is the strength of the bones affected by food changes?

The bones of pigs fed a sweetened condensed milk were but two-thirds as strong as those fed normal or evaporated (unsweetened) milk. (See conclusions, pages 85-86).

6. Does the dilution of a ration affect its food and energy values?

Apparently over-dilution of a ration tends to lessen its food value. (See conclusions, page 94).

7. In the light of the results attained in the present studies and of previous trials, the observation of the writers touching infant feeding, and the testimony of pediatricists, what broad principles may be laid down touching infant feeding?

These principles cannot be stated with safety in a sentence. They are discussed at length on pages 106-118.

I. INTRODUCTION

The several experiments cited in this bulletin were conducted with the view of adapting the findings to the feeding of the human infant. It has been said by way of criticism—and not without reason—that federal and state funds have been spent in the interests of farm productivity and prosperity rather than in the promotion of the health and wellbeing of farm occupants; that in stressing the conservation of our natural resources, we have in some measure lost sight of the need of conserving human resources; and that economics has been deemed more important than home economics and animal life better worth saving than human life. However that may be, it has seemed worth while to make some contribution at this Station to the study of infant feeding; and the present bulletin is the first fruits of this effort.

There are about 2,250,000 babies in the United States less than a year old. Fully two-thirds of them are fed artificially before they are able to digest solid food, and practically all of them consume cows' milk as their chief or sole diet before they are a year old. Nearly as many children between the ages of one and two years use cows' milk in conjunction with other foods; indeed the second year of a child's life is a critical period, especially if improperly nourished during the first year. The mortality of bottle-fed infants in the United States is nine times that of those who are breast-fed. Fischer (18, p. 344) finds "more than 90 percent of all cases of rickets among bottle babies." Maloney (9, p. 6), translator of Budin's excellent lectures, calls such a sacrifice to maternal ineptitude a reproach to the medical profession. The pitiable ignorance and helplessness concerning the correct feeding and care of infants displayed by many mothers, particularly in the congested sections of our large cities, is appalling. Much has been done of late to teach and aid mothers, more particularly along lines of sanitation; but the last word has not yet been said as to the dietetical fitness of various grades of milk to infant feeding. Not that this bulletin says the last word, but, it is hoped, a helpful word.

About one-sixth of the milk produced by our 22,000,000 dairy cows is used as food for infants and young children. Surely fitness to its special purpose of this one-sixth of the total supply is of more vital consequence than that of the remaining five-sixths; yet the study of the proper usage of this one-sixth has received but a modicum of the attention that has been given the usage of the five-sixths.

Bulletins dealing with all phases of agriculture are to be had for the asking. For the price of a post card, the farmer may receive information which would cost him hundreds of dollars and years of time to discover for himself; his wife may secure freely many valuable suggestions concerning cookery and household management; yet, prior to the establishment of the Children's Bureau of the Federal Department of Commerce and Labor, little has been thus available concerning the feeding of infants and the rearing of children, nor has it been had in any other way for the asking, except when circulated to advertise proprietary infant foods. However valuable this may be, the prime motive back of such publications is commercial, and it is not possible always to be sure of their disinterestedness and reliability. A disinterested, extensive, thoroughly careful inquiry of this matter by an experiment station ought to serve a good end, fully as much, for instance, as the expenditure of a similar effort in the encouragement of the tobacco industry.

II. CONCERNING THE PRINCIPLES OF NUTRITION

FOOD NUTRIENTS

A brief review of the nature and functions of the several food nutrients may be of service, even though it represents in the main the rethrashing of old straw; for this bulletin is likely to fall into the hands of some persons not well informed touching the present ideas as to the principles of food nutrient usage.

Dry matter. The several food substances other than water—the ash, protein, sugar, starch, fiber, fat—grouped as a unit, constitute the dry matter. When an animal gains in weight, the water stored in its cells as well as the actual dry matter constitutes the gain.

Ash. The ash or mineral matter of plant or animal substance remains intact after all moisture has been evaporated and all organic tissues are destroyed. The skeleton structure is built from the ash constituents. If a food is deficient in available ash, the normal growth of the body fed thereon is hindered.¹

Protein. This word is of Greek origin and means "of first importance." Albumen, typified by the white of egg, casein, the essential constituent of the curd of sour milk, protoplasm, which is contained in every living cell, are proteins. It is used primarily in the construction

¹ See in this connection the discussion of rickets, pages 80-82.

of muscle and largely of those glands which secrete the digestive fluids, which themselves are rich in proteid bodies. Furthermore it is used in keeping the active organs in repair, in replacing waste products. Obviously a young, growing, active animal requires a larger proportion of protein in its food than does an older animal.

Carbohydrates. There are many classes of carbohydrates. Such common substances as starch, sugar and fiber are carbohydrates, composed of the same three chemical elements, carbon, hydrogen and oxygen. The various starches differ physically, but chemically, and probably dietetically, are essentially alike; and there are many sugars, some sweeter than others. The animal body consumes much but contains little of a carbohydrate nature, and this is stored temporarily in the liver as glycogen. It passes into circulation as needed in the form of dextrose. Starches, sugars and kindred bodies when assimilated are utilized to maintain the body temperature and to furnish muscular energy. Every movement involving muscular activity, whether voluntary or involuntary—the beating of the heart, digestive processes, walking, working—uses up more or less of the energy furnished by food previously eaten and assimilated. When more food of a carbohydrate nature is consumed than an animal needs to maintain its body temperature and to perform its work, the excess, or a portion of it, under normal conditions is stored in the body in the form of fat, which reserve store may, if necessary, be utilized later for similar work to that performed by this class of foods when first consumed.

Fat. Fat occurs in almost every food. It is composed of the same three chemical elements as are starch and sugar but in different proportions, being enough richer in carbon so as to yield when consumed approximately two and a quarter times as much heat or energy as does an equal weight of carbohydrates.

Water. The water present in milk, meat or other foods is in the same state in which it exists in nature. Some foods that apparently are solid—for example, root crops—contain from 90 to 97 percent water, whereas other foods—such as oatmeal, cornmeal, flour—contain from 5 to 10 percent. It is indispensable, yet it is not in itself a true food, since it neither builds tissue, supplies energy nor liberates heat.

One should not infer, however, from these statements that foods are made up of simple substances. There are many forms of protein, all of them highly complex in their composition; the carbohydrates are multitudinous, though less complex in composition than the proteins; and there are several fats, solid, liquid and semi-solid. However, these

three groups, the proteins, carbohydrates and fats, have in a general way definite characteristics and definite functions.

Other food substances. Aside from these tangible nutrients there exist certain entities, be they substances or properties, as yet not clearly understood, which appear to be concerned with rendering the cruder compounds more available to the uses of the growing young. These seemingly essential, powerful, intangible agencies, "lipoids," "vitamines," etc. (36), have been shown to be intimately associated with the fat of milk and with the yolk of egg but not to be associated with body fats; yet normal growth apparently demands, not only that protein be furnished for muscle building and ash for bone construction, and that a sufficiency of energy be available to body uses in the form of sugar, starch, or fat, but that these intangibles be also present.

While the assimilation of moderate amounts of fat tends to conserve protein by providing a source of body energy which otherwise might have to be supplied by the protein of the food, its excessive assimilation has been shown clearly to be detrimental. Animal activity has an important bearing on the building of a strong muscular system, or, in other words, on protein storage. A high fat ration tends to induce sluggishness, and this sedentary habit in turn conserves energy which is stored in the form of fat and tends to retard the formation of muscular tissue from the protein in the food. The ingestion of too much protein, on the other hand, e. g. the long continued consumption of skimmilk or buttermilk, overtaxes the excretory system and results in unbalanced growth and lack of "condition."

These points, already well understood by students of animal nutrition, were emphasized by the results of the trials now under consideration.

NUTRITIVE RATIO

The term "nutritive ratio" is used to indicate the ratio of the protein or "muscle forming" nutrients to the carbohydrates and fat or "heat producing" nutrients. Since the energy value of protein approximately is the same as that of sugar or starch (carbohydrates), while fat yields 2.25 times as much energy, it is the universal custom, indeed obviously it is necessary, in calculating nutritive ratios to multiply the fat percentage of a food or ration by 2.25 in order to place its

nutrients upon a basis comparable with that of the other groups. Hence:—

$$\text{Nutritive ratio} = \frac{(2.25 \times \text{fat}) + \text{carbohydrates}}{\text{protein}}$$

For example, if a given milk contains 0.75 percent ash, 3.5 percent casein and albumen, 4.85 percent milk sugar, and 5.15 percent fat, its nutritive ratio is calculated as follows:

$$\frac{2.25 \times 5.15 (\text{fat}) + 4.85 (\text{carbohydrates})}{3.5 (\text{protein})} = \frac{16.44}{3.5} = \frac{4.7}{1}$$

The 5.15 parts of fat and 4.85 parts of milk sugar have a combined heating, or energy producing, value equivalent to that of 16.44 parts of sugar or starch. The ratio between the two classes of nutrients is found by dividing the total "starch value" of the milk sugar and fat (16.44) by the protein percentage (3.5). This is usually written: N. R. = 1 : 4.7, and indicates that for every one part or pound of protein there are 4.7 parts or pounds of carbohydrates and of fat, the latter being reduced to a carbohydrate or starch basis.

It is commonly held that the protein and carbohydrates in the food of a mature animal, used only for purposes of energy and repair, should bear a relation of from 1 : 8 to 1 : 9, while that of young and growing animals, which obviously need relatively much more protein, should bear a relation of from 1 : 3 to 1 : 4.

"STARCH EQUIVALENT" RATIO

The "starch value" of a food is obtained by adding its contents of the three nutrients, protein, carbohydrates and fat, having first multiplied the fat content by the factor 2.25. Using the above example the "starch value" of the milk would be $3.5 + 4.85 + (5.15 \times 2.25) = 19.94$. In other words, nearly 20 pounds starch and approximately 22 pounds of good wheat flour would be required to be equivalent in energy value to 100 pounds of such milk. The "starch value" of organic tissue may be determined thus from its analysis.

The ratio between body tissue produced and the food consumed, both calculated to the "starch value" basis, the writers have termed for convenience the "starch equivalent ratio." It represents an attempt numerically to express in simple form the units of food required

to produce one unit of gain and furnishes a ready means of measuring food efficiencies.

CALORIE RATIO

The calorie is the universal physical unit of heat. The amount of heat which is required to raise the temperature of one gram of water from 0°C. to 1°C. is a calorie. When combustible substances are completely oxidized, a definite quantity of heat is evolved therefrom. Since a gram of most substances contains many such units, it is customary, in order to avoid the use of over-large figures, to employ a unit a thousand times as great, and to express energy values in terms of so-called "large Calories," written with the small letter c capitalized thus, "Calories." A "Calorie" is equivalent to a thousand calories. The heat or fuel value of a given fodder or feed, for example cornmeal, or a given nutrient, for example cane sugar, represents its power when completely consumed to warm a given amount of water to a given extent. The fuel value of one gram of starch or other carbohydrate, or of one gram of protein, is 4.1 Calories, and of one gram of fat 2.25 times as much, or 9.23 Calories. It follows, then, that the total number of Calories of energy pertaining to any food expressed, as only it can be expressed, in numerical terms, is 4.1 times greater than is its "starch value." Hence the ratio existing between the Calories in the food consumed and in the body gain is identical with the "starch equivalent" ratio hitherto explained.

MAINTENANCE REQUIREMENT

The amount of digestible nutrients required to maintain an animal at constant weight and constant body composition varies with its size and form, its activity and the temperature of its habitat. The units of energy required under any given circumstances to maintain an adult can be measured readily. But it is difficult to determine this requirement for maintenance purposes for an animal which is increasing constantly in weight and changing in its body composition. Growing farm animals, fed an amount of digestible nutrients theoretically sufficient to maintain and only to maintain their body weight, no provision being made for gain in weight, have continued slowly to increase in height, utilizing material previously stored in their tissues for the growth and extension of their body frame and filling these tissue cells with water until, after an interval of some months, death has ensued.

In the trials now under consideration, in order to facilitate the interpretation of results obtained in feeding various grades of milk, it seemed desirable to express their efficiencies as measured by the units required for maintenance and growth. Young pigs, indeed "baby pigs" were used. So far as could be determined by search through literature, maintenance factors for such animals were lacking at the time when the trials were begun; and obviously they are difficult to attain. After much study of this matter, Dietrich's maintenance factors for young growing pigs¹ were used—0.1 pound digestible protein, 0.4 pound digestible carbohydrates, 0.04 pound digestible fat, daily per 100 pounds body weight. He stated in correspondence that while these factors might not be exact or final they were, in his judgment, the most nearly accurate available. If more accurate factors are developed later, they will in no wise affect the relativity of the results. It will be noted that this maintenance requirement differs quite profoundly from those commonly accepted as applicable to the maintenance of mature animals, in that it prescribes a larger proportion of protein.

The starch or energy values of the food consumed and of the resulting tissue in rapidly growing pigs were calculated in the trials herein reported. They store as tissue about 30 percent of the energy consumed and naturally a portion of the remaining 70 percent must be utilized for maintenance. The Station desired to determine the amount required for maintenance and to note its relation to the amount stored as tissue. Since both the amount required for maintenance and the amount consumed are proportioned to growth, the percentage utilization of the food is relatively similar whether calculated from the total Calories ingested or from the amount consumed in addition to maintenance requirements.

III. PURPOSE OF THE EXPERIMENTS

The experimental trials discussed in this bulletin were designed to throw light on the following questions:

1. What fat grade of milk is best adapted to the growth and well being of young animals?
2. Is a milk the fat globules of which are relatively small, on that account preferable in the feeding of young animals to a milk the fat globules of which are relatively large?

¹Ill. Sta. Circ. 126, p. 16 (1907).

3. Does the process of homogenization improve milk as a food for young animals?
4. Are condensed (sweetened) or evaporated (unsweetened) milks as well adapted to infant feeding as is normal cows' milk?
5. To what extent is the strength of the bones affected by food changes?
6. Does the dilution of a ration affect its food and energy values?
7. In the light of the results attained in the present studies and of previous trials, the observation of the writers touching infant feeding, and the testimony of pediatricists, what broad principles may be laid down touching infant feeding?

Comparative trials of grade Holstein-Friesian and Jersey milks were made in the attempt to secure answers to the first two questions, since the battle has raged more particularly between the advocates of these breeds. It hardly need be said that the efficacies of the several rations were not determined by gross gain weights, but by dry matter gains, by a study of the composition of those gains, and by the clinical evidences of thrift and vigor or of malnutrition.

CONCERNING BREED CLAIMS

It has been often claimed, particularly by certain enthusiasts, that Holstein milk is superior to that of other breeds, especially Jersey milk, as a food for the young. In support of this view it is said that while difficulty is seldom experienced in rearing Holstein calves on their dams, Jersey calves often suffer from digestive disorders when so nourished, and that Jersey calves fed Holstein milk are likely to thrive better than those fed Jersey milk. It has been observed frequently that calves fed milk rich in fat have died from acute indigestion or from chronic diarrhoea, while those receiving milk of a lower fat content suffered no intestinal disorders and grew vigorously.

Some physicians maintain that in their experience Holstein milk proved superior to Jersey milk in infant and invalid feeding, although seldom stating wherein it excels. Gilbert (20), a strong advocate of Holstein milk, attributes its superiority to its lower fat content and to the smaller size of its fat globules. This point of view is set forth in medical literature (18, p. 101), is supported by certain laboratory tests (20), and by at least one theory of fat digestion which holds that the

fat is first emulsified and that much of it then is directly absorbed through the intestinal walls before it undergoes any chemical change. If this statement is correct, the smaller the fat globule at the time when it is ingested the more easily can it be emulsified, thus requiring less intestinal or glandular energy for its assimilation. That this point of view has weight is shown by the fact that many parents are willing to pay a higher price for this type than for other types of milk for infant feeding. On the other hand much testimony may be cited favoring the use of high fat milk (3, pp. 5 and 7). In fact so many statements diametrically opposed to each other, if not actually misleading, are made in support of both claims, that it seemed well worth while to attempt to secure data which might be pertinent.

CHEMICAL AND PHYSICAL DIFFERENCES BETWEEN HOLSTEIN AND JERSEY MILKS

Holstein and Jersey milks differ in at least four respects, namely:

1. In fat percentage.
2. In the ratio of fat to solids-not-fat.
3. In the size of the fat globules.
4. In the proportion of albumen to casein.

1. Holstein milk usually contains from 3 to 3.8 percent fat, while Jersey milk usually carries from 5 to 7 percent fat. Reducing percentage compositions to a dry matter basis, about 25 percent of the solid matter of Holstein milk is fat whereas about 40 percent of the solid matter in Jersey milk is fat.

2. Holstein milk contains less fat in proportion to the solids-not-fat than does Jersey milk, the ratios being 1:2.4 and 1:1.8 respectively.

3. Many measurements, including some made in the early days at this Station (35), have established that the average Holstein fat globule is 2 microns or 1-12,000 inch, while the average Jersey fat globule is 2.8 microns or 1-9,000 inch in diameter. It is understood generally, too, that the fat globules of human milk are as large as those of cows' milk (47, p. 321).

One hundred counts on each of four samples of human milk, four of Holstein milk and five of grade Jersey milk, made at this Station, stated as microns, afforded the results shown in the following table:

TABLE I—SIZE OF FAT GLOBULES (MICRONS)

25 large globules			25 small globules			50 at random			
Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	
HUMAN MILK									
Human milk	5.47	8.35	3.39	1.39	5.26	0.46	2.61	6.62	0.49
Human milk	5.73	8.87	3.52	2.00	2.90	0.91	2.78	9.58	0.33
Human milk	4.55	7.40	2.93	1.30	3.23	0.42	1.70	9.49	0.33
Human milk	5.65	12.52	3.42	1.37	3.26	0.42	2.07	9.78	0.33
COWS' MILK, COMPOSITE SAMPLES									
Jerseys	9.36	17.08	5.67	1.48	3.55	0.46	3.81	10.60	0.55
Holsteins	8.26	17.77	4.08	1.10	3.26	0.33	2.14	9.13	0.36
INDIVIDUAL GRADE JERSEYS									
Angie	7.69	22.82	4.17	2.59	4.37	0.39	3.67	8.08	0.49
Grace	7.09	15.00	3.49	1.92	3.85	0.49	3.37	15.52	0.33
Isadore	7.81	19.23	5.22	2.04	4.01	0.55	3.78	8.61	0.52
Laura B.	6.70	16.30	4.21	1.54	3.26	0.49	3.60	14.02	0.29
Tansy	7.27	13.69	4.69	1.44	3.26	0.33	2.94	9.00	0.39
INDIVIDUAL GRADE HOLSTEINS									
Bontje	5.46	7.60	3.94	1.21	3.75	0.33	2.68	7.66	0.49
Elbaje	4.91	8.08	3.26	1.38	2.51	0.46	2.25	7.24	0.52
Fyra	5.39	7.89	3.42	1.31	3.26	0.42	3.03	17.21	0.33
Phoebe	5.19	7.73	3.72	1.66	3.19	0.55	2.67	6.52	0.55

The average diameter of the fat globules in these samples of human milk was intermediate between those of the grade Holstein and Jersey milks. It is of interest to note that the fat globule in swine's milk is much smaller than that of the human, while those of the mouse and rabbit are the largest (50, p. 19); in fact an average fat globule of mouse's milk is twice as large as the maximum and thrice as large as the average fat globule in cows' milk (47, p. 320). These facts do not seem to support the theory that the smaller fat globule is materially to be preferred.

Photomicrographs, displayed opposite page 32, afford a fairly clear idea of the relative sizes of grade Holstein, grade Jersey and human milk fat globules. The effect of homogenization at 85° F. and at 185° F. as a means of subdividing the fat globules in grade Jersey herd milk is also shown by means of photomicrographs in adjacent plates.

4. The comparative proportions of casein and albumen in grade Holstein and Jersey milks are: Holstein, 77.5 and 22.5; Jersey, 82.3 and 17.7.

These four distinctions as set forth in the last two pages are clear and tangible. As much cannot be said, however, for some distinctions

which have been attempted. For example the claim is made sometimes that the greater strength, docility and contentedness of the Holstein imparts to her milk a "vitality" not possessed by milk of other breeds. No attempt was made to determine the validity of this assertion; neither was any attempt made to study the effect, if any there be, of variations in the proportion of albumen to casein. The relation of fat contents and of fat globule sizes were the only matters taken into account.

It will be seen readily that in any experiment designed to test the points at issue, it was necessary separately to study the effect of the two variants, the fat content and the size of fat globule. Obviously to feed Holstein as against Jersey milk directly would serve to obscure the effect of these two variants to such an extent that it would have been impossible to have stated the outcome with any degree of certainty.

IV. PREVIOUS WORK IN THIS FIELD

During 1904 Beach, then of the Connecticut (Storrs) Station, published the results of an investigation on "The Food Value of a Pound of Milk Solids" (6). He found that the solids derived from milk comparatively poor in fat, when fed to calves, lambs and pigs, produced gains in weight more economically than did those derived from rich milk. His conclusions are succinctly displayed in table II:

TABLE II—MILK SOLIDS REQUIRED FOR ONE POUND OF GAIN

	Milk poor in fat	Milk rich in fat
Average two pairs calves, 45 days	1.03	1.18
Average first trial, two pairs pigs, 40 days	1.36	1.77
Average second trial, two pairs pigs, 30 days	1.40	1.56
Average two pairs lambs, 60 days	1.08	1.37
Average of eight pairs of animals	1.22	1.47

FEEDING TRIALS WITH CALVES

The work at this Station was begun in the summer of 1907 by C. L. Beach, then animal husbandman, who fed different grades of milk to eight calves. The following results were secured:

Durtje's calf: Holstein; fed four weeks on Holstein milk; made good gain; in good condition; chemical composition of animal not determined.

Rosel's calf: grade Jersey; fed four weeks on three percent milk; made good gain; chemical composition of animal not determined; healthy.

Jane's calf: grade Jersey; fed Holstein skimmilk four weeks; made moderate gain; was judged by butcher to be "poor veal."

Mona's calf: grade Jersey; fed 2.5 percent Holstein milk for four weeks; made fair gain; judged by butcher to be "fair" veal.

Sabra's calf: grade Jersey; fed 5 percent Holstein milk; made good gain; body tissue contained more fat than that of animals above; judged by butcher to be "good veal."

Angie's calf: grade Jersey; fed Jersey skimmilk four weeks; made poor gain; judged by butcher to be "good veal."

Ardelle's calf: grade Jersey; fed 2.5 percent Jersey milk four weeks; made fair gain; judged by butcher to be "good veal."

Peggy's calf: grade Jersey; fed 5 percent Jersey milk four weeks; made good gain; judged by butcher to be "good veal."

The data secured in the chemical laboratory from the analyses of sections from several of these calves, together with other details pertaining to this trial, are summarized in tables III and IV.

TABLE III—FEEDING TRIALS WITH CALVES

	Age days	Live weights			Food consumption		
		At birth lbs.	Final lbs.	Gain lbs.	Protein lbs.	Fat lbs.	Milk sugar and ash lbs.
Jane, Holstein skim.....	13	55.	110.	40.8	18.7	0.36	38.07
Angie, Jersey skim.....	15	52.8	108.8	38.	22.31	0.25	31.04
Mona, Holstein 2.5%...	11	57.6	110.5	41.	14.81	12.85	30.39
Ardelle, Jersey 2.5 %...	12	57.8	110.8	41.3	17.7	14.45	24.88
Sabra, Holstein 5%....	6	62.8	117.3	48.8	11.87	19.19	25.43
Peggy, Jersey 5 %.....	9	53.2	111.	49.3	14.7	20.69	21.35

TABLE IV—EFFECT OF FOOD ON COMPOSITION OF VEAL

Name of dam	Sampled from lean portion of	Nature of food	Water	Dry matter	Protein	Fat	Butcher's veal judgment
Jane, Hind quarter, Holstein skim..			74.57	25.43	22.21	0.95	Poor
Jane, Fore quarter, Holstein skim..			75.86	24.14	20.50	1.52	Poor
Angie, Fore quarter, Jersey skim...			76.14	23.86	21.00	1.79	Poor
Mona, Hind quarter, Holstein 2½%..			73.00	27.00	21.33	3.39	Fair
Mona, Fore quarter, Holstein 2½%..			72.87	27.13	20.38	4.89	Fair
Ardelle, Fore quarter, Jersey 2½%..			74.75	25.25	19.75	4.86	Good
Sabra, Hind quarter, Holstein 5%...			73.09	26.91	19.13	5.45	Good
Sabra, Fore quarter, Holstein 5%...			72.07	27.93	19.58	6.61	Good
Peggy, Fore quarter, Jersey 5%.....			73.86	26.14	19.37	5.82	Good

The feeding was conducted for 29 days, beginning when the calves were from 6 to 15 days old. The nature of the food consumed, birth

weights, the final weights and the total gross gains in weight are recorded, as well as the pounds of protein, fat and milk sugar and ash consumed during the feeding period. Fat consumption is the chief variant, ranging from a fraction of a pound when skimmilk served as food to more than 20 pounds when grade Jersey milk was fed.

Table IV shows the effect of the varying amounts of fat consumed on the composition of the lean meat taken from the hind and fore quarters. Speaking broadly, the flesh of the skimmilk-fed calves carried more water and protein and less dry matter and fat than the flesh of those fed rich milk, while the flesh of those fed 2.5 percent milk in all these respects was intermediate.

Even in these relatively crude tests, the effect of the change in the fat content of the food is reflected clearly in the body composition.

CHOICE OF ANIMALS

It was early evident that calves were not adapted to the purposes of this particular trial. In the first place the initial body composition of the animals could not be known or even approximately estimated. Then again, Jersey calves weigh at birth from 40 to 80 pounds, whereas Holstein calves weigh from 80 to 120 pounds, and obviously they vary greatly in frame and development. Furthermore individual differences are so extreme that many trials would have to be made in order to secure trustworthy data.

In order to overcome these difficulties it was decided thereafter to use "baby pigs." Pigs are born in litters, thus enabling six or more of the same age and inheritance to be used in the same test. Since variations in individuality found in litters of mixed breeding is great, all of the pigs used in these trials, after the first two runs, were pure-bred animals. Each litter consisted of eight or more, and the seven most uniform animals were selected. After the second season's work, all pigs were secured from the large breeding establishment of W. H. Miner, Chazy, N. Y. It has occurred frequently that two litters, comprising 12 out of the 18 pigs under test, had been sired by the same boar and were of the same age to a day, the remaining six being of the same pure blood and varying only one or two days in age from their mates. Yet it was many times made manifest that even the pigs thus carefully selected differed more or less in general intelligence as well as in their ability to endure adverse feeding, and especially as to their fat tolerance.

CONCERNING THE APPLICABILITY OF THE RESULTS SECURED IN TRIALS
WITH PIGS TO HUMAN INFANT FEEDING

The very pertinent question may be asked at this point whether results attained in feeding pigs are or are not applicable to the feeding of the human infant. It may be said in this connection that students of animal nutrition long have recognized the similarity existing in the fundamental digestive processes of all animals.

Innumerable studies of the influence of nutrition, fatigue, excitement, etc., on milk production have been made with the cow, mare, goat, and bitch, but little or no systematic observation, much less experimental study, has been made in relation to the human. The horse has been used in Abderhalden (1) in a study of protein usage, and by Zuntz (60) in work upon the respiratory quotient. Fat digestion has been studied using rabbits and dogs (37, p. 76); and Pettenkofer and Voit fed lean meat to a dog, noting the carbon balance (25, p. 131).

Much study has been given to the question whether protein may form fat in the animal body. Cremer starved a cat and then fed it lean meat, while Rubner performed similar experiments with a dog (40, pp. 143-144). Pfluger "proved that protein may serve as a source of muscular energy by feeding a dog for seven months exclusively upon meat, practically free from fat" (49, p. 105). "Rather more satisfactory and direct proof" of the formation of fat from protein was obtained by Hofmann (25, p. 131), who fed a quantity of the larvae of calliphoria, or common blow-fly maggots, upon blood, the dry matter of which is about 80 percent protein; and inasmuch as the maggots increased from 700 to 1,100 percent in their fat content, he concluded that animals can convert protein into fat. Lusk states that "such a procedure reasonably explains the formation of fat from protein" (40, pp. 145-146). Weinland (25, p. 132) used the larvae of the ordinary blow-fly for this purpose and arrived at the same conclusions, as did also Niverstein working with paramoecium (42, pp. 140-143). Armsby (4, p. 54) states that "it can hardly be assumed that the actual processes of metabolism in the body tissues are fundamentally different in the different species of mammals. Sherman (49, p. 108), commenting on Lusk's work, remarks that while the latter's "conclusions are based mainly upon the results of trials with phloridzinized dogs, there seems to be no doubt that in healthy man also a large part of the protein eaten may take the form of carbohydrate in the course of its metabolism in the body." And, finally, it is of interest in this connection to note that

in "A Study of the Nutritive Value of Some Proprietary Infant Foods," the Misses Wheeler and Beister (55, pp. 169-183) made use of albino mice.

If conclusions reached by experimentation upon the mare, cow, goat and sheep in relation to the effect of food on the milk flow, and upon the dog, rabbit, cat, blow-fly, maggot and paramoecium with respect to protein usage, have weight as evidence in settling these questions, and if albino mice may serve effectively as means wherewith to study the value of infant foods, the writers believe that with some degree of reason they may claim that the results of nutritional work in which the pig is used, an animal which is recognized to be in reality physiologically very similar to the human, should furnish data of value in the study of the feeding of the human; a belief which is quite in accord with the conclusion numbered 8 on the following page, and with Chapin's statement that "it is self-evident that the infant belongs to the animal kingdom and is accordingly subject to the general laws of animal nutrition" (13).

In this connection may be mentioned an interesting and significant feeding trial carried out some 20 years ago by Sanford and Lusk (40). These investigators fed three new born pigs for two weeks on skimmilk, skimmilk and lactose, and skimmilk and dextrose. Ten years later Miss Wilson (56), working in the physiological laboratory of the Bellevue Hospital Medical College, fed a couple of litters of new born pigs. Three pigs were killed and the analysis used as check on the remaining six which were fed carefully for 14 to 16 days. She summarizes as follows:

"1. Skimmed cow's milk, with or without 2 or 3 percent of added lactose or dextrose, is normally absorbed by suckling pigs.

2. Two pigs fed on skimmilk from 14 to 16 days gained 26.4 and 66.8 percent in weight. Two pigs fed on the same skimmilk, with 2 and 3 percent of lactose added, gained 79.7 and 88 percent in weight. Two pigs fed on the same skimmilk, with 2 and 3 percent of dextrose added, gained 73.6 and 64.4 percent in weight.

3. Those fed with plain skimmilk gained 114 and 218 grams in weight for every 1,000 physiologically available Calories in the food. The lactose pigs gained 222 and 215 grams per 1,000 Calories in the food. The dextrose pigs both gained 213 grams per 1,000 Calories in the food. Except in the case of one ill-nourished skimmilk pig, the growths of the sucklings stand in a constant ratio to the Calories in the food.

4. The pigs fed on plain skimmilk used 23 and 35 percent of the proteid in the food for tissue growth, the lactose pigs used 38 to 44 percent, and the dextrose pigs 48 to 42 percent.

5. All the pigs of the second litter gained in fat when fed on plain skimmilk or on skimmilk with sugars.

6. The percentage of calcium in the bodies of the pigs diminished with their growth. There was considerable and normal deposition of calcium in the pig, and this was proportional, not to the calcium in the food, but to the growth of the animal.

7. Not only is the growth in grams of the pigs proportional to the Calories in the food, but the number of Calories retained in the tissue substance during growth is proportional to the Calories in the food. Eighteen to 19 percent of the Calories in the food were found stored in the tissue growth of the pigs fed on the three varieties of skimmed milk.

8. There seems to be striking evidence that the suckling pig reared on skimmed cow's milk conforms to the same laws of nutrition as the breast-fed infant."

SCOPE OF THE PRESENT INQUIRY

Most investigators of problems involved in the study of infant feeding have been handicapped by inadequate means wherewith to carry out their plans. This is true particularly of some of the earlier work. Conclusions necessarily have been drawn from insufficient data. Thus Sherman (49, p. 109), discussing the formation of fat from protein, gives evidence derived from the feeding of one cat for eight days; Kellner (37, p. 74), discusses at length the results attained with one dog fed for five days; while Lusk (40, p. 237), in his study of the influence of food, or its absence, upon the fat content of milk, bases his statements upon an experiment wherein one goat was fed for nine days. Kellner is correct in emphasizing the necessity of using a larger number of animals in order to eliminate individual peculiarities. He suggests "ten, even better fifteen or twenty" as a suitable number (37, p. 239).

Attention is drawn here to the large number—162—of very uniform animals used in the tests now under review and to the relatively long period of experimentation, totalling 6,865 "pig-days." In these respects the writers have been favored as compared with earlier workers in this field.

V. PROCEDURE

CARE OF THE BABY PIGS

The experimental animals were housed in a small building especially designed for the purpose of these trials. The floor was cement, shavings were usually employed as litter, and individual pens were used.

Each baby pig was weighed on its arrival. The pig in each lot whose weight was nearest the average was killed at once, its body prepared for analysis in the manner described on page 26, and the results used as a check for that litter. The remaining six were given warm water to drink at the outset, followed by skimmilk and warm water and, later, by sweet skimmilk. They were kept on this diet from one to three days until they had recovered from the fatigue and excitement incident to their journey. Frequently the change in surroundings or food or the effect of the journey induced diarrhoeal disturbances, but a daily diet of skimmilk and subsoil earth remedied the situation before they were entered upon the experiment. Clean subsoil earth was daily offered and usually consumed, especially by those on the rich milks. All unusual occurrences, such as illness, its treatment, etc., were noted. The records made by any animals which manifestly did not thrive well were discarded although the analyses were made and the clinical evidences noted. Indeed, some of the most significant results secured were supplied by animals which "went bad." There were several instances of this kind in the earlier trials, before moist, subsoil earth was regularly administered.

Since no data were available indicating how much food is required for the maintenance and growth of young pigs, they were given all they would consume readily. Repeated failure to display a keen appetite at meal time was followed by a reduction in the amount of food furnished. At first they were fed thrice daily, but later only twice.

The duration of these trials was intended to fall within the age limit when the development of the pigs would be comparable with that of a child during its normal milk-consuming period; yet their length varied somewhat, depending more particularly upon the condition of the animals and the season. The infant pig is more fully developed at birth than is the human babe and it matures more rapidly. The experimental pigs were from four to five weeks old at the beginning of the trials, an age comparable to that of a human infant four to five months old. For a few weeks thereafter each week of a pig's life ap-

proximately corresponds to a month in a child's life; yet a year-old pig is more mature than is a human being 12 years old. However, to have limited the duration of the experimental feeding exactly to the comparable period would have curtailed the tests, and it seemed the part of wisdom to continue them for a somewhat longer time than that which covered in a comparable way the milk diet life of the child. Accurate account was kept and frequent samples drawn of all food consumed and of gains in weight.

FOOD

The milk used was furnished by grade Holstein-Friesians and registered and high-grade Jerseys.¹ In determining the relative nutritive values of these two milks (VII-VIII, pages 31-55), obviously it was necessary to standardize them. It is evident that if the test had been made directly with the milks as yielded, it would have been impossible to have asserted whether divergencies in outcome, if any there were, were due to variations in the fat content or in the size of the fat globules. Hence all the milks were centrifugally skimmed and the Holstein cream mixed with Holstein skimmilk and the Jersey cream with Jersey skimmilk in definite proportions in order to secure the several desired grades. By thus standardizing the milks, their fat contents were made essentially identical and the diverseness as to size of the fat globules was made the chief variant. In order to determine the issue the more rapidly and thoroughly, the pigs were fed three grades of milk, namely, skimmilk, milk standardized to test approximately 2.5 percent of fat, and milk standardized to test approximately 5 percent of fat. Homogenized milk (IX, pages 59-69) was processed in the dairy laboratory. The condensed and evaporated milks (X, pages 69-70) which were used were standard commercial brands.

SLAUGHTERING TECHNIC

In due time each pig was taken to a well equipped slaughter laboratory.

The procedure of sample taking and preparation was as follows: Each animal was weighed and then partially anesthetized with chloroform or ether, suspended by its hind legs and its blood drawn into a tarred porcelain dish through an incision in the throat. The blood was

¹ From this point onwards in this discussion for purposes of simplicity the words "grade" and "registered" will not be repeated.

weighed and at once evaporated in a large drier at a temperature of about 120°-140° F. Preliminary work indicated that satisfactory results were secured if the blood did not coagulate before being placed in the oven. The blood-free carcass was weighed, the ventral median line cut, and the abdominal and thoracic viscera removed, weighed, passed through a meat chopper, mixed and suitably sampled. The carcass was then halved through the median plane and the right half photographed and the femur removed for bone strength tests while the left half was carefully and promptly "boned out." The half skeleton, together with some small amounts of soft tissue necessarily left thereon, was passed through a "green bone cutter," mixed and subsampled. The remaining soft tissue was weighed, cut into pieces of convenient size, passed through a meat chopper, mixed and subsampled. The entire carcass of the check animal was similarly prepared at the outset of each trial.

The several portions taken for analysis were promptly dried and, when possible, ground in a mortar. In several cases, especially when dealing with samples of meat and skin, a partial ether extraction of the fat was necessary as a preliminary to grinding, and was accomplished by a 24-hour treatment in a large and special separatory funnel containing a perforated tin tube with a removable bottom. The fat content of the filtrate was determined by the evaporation of triplicate aliquots. The partially extracted residue was dried, ground and analyzed.

Throughout the operations a careful check was kept on all weights and the several analyses of blood, viscera, skeleton and soft tissues were finally calculated to the basis of the original animal.

VI. THE CHECK PIGS AND THE STANDARD-FED PIGS

GENERAL STATEMENT

One hundred and sixty-two pigs, representing 23 litters, were used in these trials. The body composition of each pig—except four which died—was determined. Twenty-four were killed at the outset of the several trials in order that the chemical data thus secured might be used as a check, indicative of the original body composition of the pigs in the several litters which were experimentally fed.

The pigs were fed in groups of 6 to 18 for from 30 to 67 days, a total of 6,865 "pig-days" equivalent to 18.8 years of pig-life. The data secured from the analyses of the carcasses of 29 of the pigs are not used, being omitted from averages because the animals showed clearly

during life and on post-mortem that they were suffering from malnutrition, a situation reflected also in the analytical results. The final results are derived from the testimony of 129 healthy pigs, or 80 per cent of the number used.

GENERAL OUTLINE OF WORK ON WHICH RESULTS ARE BASED

Number of pigs used in investigation	162
Representing litters	23
Total pig-days	6,865
Number of carcasses analyzed	158
Number of carcasses not analyzed (died)	4
Pigs, other than check, used in compiling average	105
Check pigs analyzed	24
Carcasses analyzed; results omitted from average	29

COMPOSITION OF BABY PIGS WHEN FEEDING BEGAN

Table V shows the body composition of the 24 individual pigs used as checks. Nos. 1 and 2 in "run A" were from the same litter; and the results attained indicate that baby pigs from the same litter are not unlike in composition. The others, each from a different litter, show somewhat larger variations in composition, a fact which is particularly recognizable in their fat contents. These differences are brought out clearly in the column headed "Ratio of Protein to Fat"; for example, No. 153, 20.36 percent fat, ratio 1 : 1.4; No. 41, 5.8 percent fat, ratio 1 : 0.31. Since these baby pigs had been nourished in every case by their own mothers and were thoroughly normal and active, it may be assumed that the ratio of chemical substances of their bodies must have been approximately normal and best for their health and well being.

Their weights varied from 5,150 to somewhat over 13,200 grams, or from about 12 to nearly 30 pounds, the average being 8,326 grams, or 18.3 pounds.

The average body composition of 24 pigs, four to five weeks old, representing 23 litters, not one of which ever had received food other than its own mother's milk, appears at the bottom of the table. The average baby pig seems to consist—from the chemical point of view—of one-third dry matter and two-thirds water, the ash comprising one-tenth and the protein and fat each a little more than three-sevenths of the dry matter. The average composition of a child's tissue at birth as stated by Pfaundler and Schlossmann (46, p. 338), is shown for purposes of comparison. It is interesting to note the similarity in the ratio of protein to fat, i. e., 1 : 1.05 in the child's tissue, 1 : 0.95 in that of the baby pigs.

TABLE V—CHEMICAL COMPOSITION OF YOUNG PIGS (CHECKS)

Run	No.	Weight kilos	Water percent	Dry matter percent	Ash percent	Protein percent	Fat percent	Ratio protein to fat 1:
A	1	8.951	65.90	34.10	3.51	16.37	14.39	0.85
	2	8.093	65.29	34.71	3.64	16.81	14.31	0.85
B	17	7.860	67.84	32.16	3.36	15.50	12.81	0.83
	25	6.950	67.96	32.04	3.29	14.13	14.15	1.00
C	40	5.954	74.42	25.58	3.05	15.25	6.98	0.46
	41	7.101	74.68	25.32	3.22	16.56	5.08	0.31
D	48	5.895	69.63	30.37	2.79	14.19	12.25	0.86
	55	7.515	68.75	31.25	3.06	15.31	12.53	0.82
E	59	10.409	65.67	34.33	3.11	13.88	16.75	1.21
F	69	8.529	70.01	29.99	2.99	14.81	11.89	0.80
	76	9.461	62.98	37.02	3.13	14.63	18.94	1.32
G	83	12.244	64.63	35.37	3.15	15.81	16.05	1.02
	90	9.957	63.42	36.58	3.29	15.63	17.26	1.10
H	97	9.357	67.02	32.98	3.52	15.44	13.78	0.89
	104	11.408	67.38	32.62	3.34	15.63	13.51	0.86
J	111	13.183	64.54	35.46	3.12	15.25	17.71	1.16
	117	5.141	65.47	34.53	4.08	15.06	14.85	0.99
K	124	5.595	70.23	29.77	4.06	15.50	9.59	0.62
	132	10.097	64.53	35.47	2.84	15.81	15.44	0.98
L	139	8.545	67.98	32.02	2.86	15.81	12.67	0.80
	146	7.553	69.17	30.83	2.77	15.06	12.56	0.83
	153	6.101	61.95	38.05	2.51	14.56	20.36	1.40
	160	7.566	62.92	37.08	2.55	14.81	19.24	1.30
	167	6.359	63.38	36.62	3.09	14.44	17.87	1.24
Average		8.326	66.62	33.38	3.17	15.30	14.51	0.95
Human infant			71.8	28.2	2.7	11.7	12.3	1.05

THE STANDARD PIG

After the trials had been in progress long enough to enable comparisons to be made on the chemical basis, the need was felt of some "base line," or standard of comparison. Consequently six pigs, two from each of the three litters, were fed a ration calculated to produce sturdy, thrifty pigs, without regard to the question whether its component parts could be or could not be used as food for infants.

Nos. 132, 138 and 145, one from each of the three litters, were fed milk containing 2.5 percent fat to which was added a grain adjunct made up by weight of fine cornmeal six parts, fine brown middlings, two parts, and old process linseed oil meal two parts. The nutritive ratio of the grain was 1: 7.6 and of the milk 1: 2.9. Equal weights of grain and milk solids were fed, 1.3 pounds of grain to each 10 pounds of milk. The nutritive ratio of the ration was 1: 3.5. Nos. 130, 137 and 144, one from each of the three litters, were fed skimmilk to which the same grain adjunct was added, not in amounts equal to the solids of the skimmilk, but in such amounts as

would furnish a total solid content derived from the milk and from the grain identical with that fed to the pigs fed on 2.5 percent milk. They received 1.7 pounds grain mixture to each 10 pounds of skim-milk, the nutritive ratio of the ration being 1 : 2.7. This produced a skimmilk-grain mixture with 21 percent total solids in both meal and milk. The ration was made up fresh at each feeding and fed in as large amounts as the animal would consume readily. The group receiving skimmilk was disadvantaged in that, since the energy value of fat is 2.25 times that of starch, the pigs fed 2.5 percent milk ate an energy equivalent in excess of that eaten by the skimmilk group, without being burdened by an increased total bulk of food; furthermore, the grain ration was less readily digested and, consequently, less available for tissue construction. In other words, theoretically, since the 2.5 percent group ate more, it should gain in weight more rapidly and economically than its competitor; and it did. All these standard-fed pigs made satisfactory though not unusual gains and were singled out by the veteran butcher who did most of the killing during these trials, as firm, "growthy" animals, so fine that it was "a shame to kill them."

The true average composition of these six pigs is used in connection with all these trials as a basis of comparison, as stated below:

TABLE VI—STANDARD-FED PIGS (FED 50 DAYS)

Ration Nos.	Skimmilk and 130	grain 137	144	2.5% milk and 131	grain 138	145	Aver- age
Initial weight, kilos..	8.69	6.64	8.85	10.22	7.83	7.32	8.26
Final weight, kilos...	24.75	23.60	25.74	33.00	26.12	27.50	26.79
Daily gain, grams....	321	339	338	456	366	404	371

FOOD CONSUMPTION

Total kilos	148.51	148.18	148.00	165.85	142.30	143.99	149.47
Dry matter, %.....	20.94	21.04	21.02	21.20	21.23	21.06	21.08
Ash, %.....	0.99	0.99	0.99	0.99	0.97	0.97	0.98
Protein, %.....	5.55	5.57	5.56	5.20	5.21	5.18	5.38
Carbohydrates, % ...	14.00	14.08	14.06	12.36	12.38	12.25	13.17
Fat, %	0.40	0.40	0.41	2.67	2.67	2.66	1.55

INITIAL BODY COMPOSITION

Dry matter, %.....	35.47	32.02	30.83	35.47	32.02	30.83	32.94
Ash, %	2.84	2.86	2.77	2.84	2.86	2.77	2.82
Protein, %	15.81	15.81	15.06	15.81	15.81	15.06	15.55
Fat, %	15.44	15.67	12.56	15.44	12.67	12.56	13.72
Ratio, protein to fat, 1:	0.98	0.80	0.83	0.98	0.80	0.83	0.88

FINAL BODY COMPOSITION

Dry matter, %.....	33.06	30.07	32.67	36.48	33.80	35.56	33.81
Ash, %	2.50	2.54	2.30	2.40	2.52	2.26	2.42
Protein, %	12.75	13.99	12.75	12.00	12.63	13.63	12.90
Fat, %	17.21	12.80	16.58	19.69	18.04	18.63	17.36
Ratio, protein to fat, 1:	1.35	0.92	1.30	1.65	1.43	1.37	1.35

The average individual daily gains in weight varied from 321 (No. 130) to 456 grams (No. 131). The latter animal was a very vigorous feeder, handling easily more food than did the other pigs and consuming nearly 166 kilos of food, containing 21 percent of total solids. The dry matter content of the rations was very uniform, but, owing to unlike fat contents, their energy values naturally were unlike. The effect of these differences in food values is seen plainly in the diverse dry matter, protein and fat contents and in the different protein to fat ratios of the two groups.

In the further presentation of this matter, stress will be laid on the effect of feeding milks which vary in their fat contents upon gains in weight and body composition. To illustrate how this gain and its composition were determined, the data secured on No. 145 are shown in table VII.

TABLE VII—METHOD USED TO CALCULATE COMPOSITION OF BODY GAIN

Pig No. 145	Run K	Water	Dry matter	Ash	Protein	Fat
Composition	Grams	17721	9779	621	3744	5124
when killed	Percent	64.44	35.56	2.26	13.62	18.63
Composition	Grams	5064	2256	203	1102	920
when feeding began	Percent	69.18	30.83	2.77	15.06	12.56
Composition	Grams	12657	7523	418	2642	4204
of gain	Percent	62.72	37.28	2.07	13.09	20.83

The estimated weights of the dry matter, ash, protein and fat contents of the animal at the time when the feeding trial began, based on its own true initial weight and on the composition of the check pig belonging to the same litter, subtracted from similar data obtained from the analysis of the animal at the close of the feeding period, furnish the grams of water, dry matter, ash, protein and fat retained as growth, or "gain," from which is calculated its percentage composition.

The weekly gains in weight made by the standard-fed pigs during the 50-day feeding period, expressed as percentages, appear below. All the pigs did well. The 2.5 percent milk and grain adjunct lot gained more rapidly than the other group, for reasons already indicated. No. 137 (skimmilk) doubled in weight in about 27 days, while it took No. 130, a heavier animal at the start, 36 days to do as well. No. 145 (2.5 percent milk) doubled his weight in 27 days, while the larger No. 131 took 31 days to make an equivalent gain. The two groups doubled their weights in 33 and 29 days respectively.

TABLE VIII—STANDARD-FED PIGS; PERCENTAGE GAINS

(Nos. 130, 137, 144 fed skim milk and grain; Nos. 131, 138, 145 fed 25 percent milk and grain; all fed 50 days).

	Initial weight kilos	Average 7 days	14 days	percentage 21 days	gain 28 days	at the 35 days	the end 42 days	of 50 days
No. 130	8.69	4	11	30	65	99	132	185
No. 137	6.64	16	27	50	105	152	200	255
No. 144	8.85	5	14	31	68	107	142	191
Average	8.06	8	16	36	77	116	155	206
No. 131	10.22	9	22	50	86	129	167	223
No. 138	7.83	12	27	58	94	141	176	234
No. 145	7.32	14	31	65	108	155	205	276
Average	8.46	11	26	57	95	140	181	241
Average 6 pigs.....	8.26	10	21	47	86	129	168	224

Other calculations dealing with these standard-fed animals, based on the results shown in table VI, appear at several points in the further discussion.

VII. SKIM-, MEDIUM AND RICH MILKS

Information was sought in these trials concerning several matters: the amount of fat which should be fed; the ratio the protein content should bear to the fat content; the effect produced upon the health, growth and body composition of the several animals by feeding milks of varying fat contents; the kind of body tissue formed when rations of different but definite chemical composition are fed; and the bearing of the results attained upon the feeding of the human infant. No attempt was made to throw light on problems of economical pork production.

In the special series of trials now under review in section VII of this bulletin, as in the others (VIII-XII) hereinafter discussed, the general procedure as to the care of the pigs outlined on pages 24-25 was carried out. Several different lots were used in the present series and the results are derived from data secured during two seasons. Not only were check animals employed at the start, but control animals also were fed throughout all the work during several seasons. Hence the large numbers shown in table IX; 16 pigs for 51 days on skim-milk; 27 for 48 days on 2.5 percent milk; and 15 for 46 days on 5 percent milk. Indeed, the data appearing in tabular form throughout the remainder of the bulletin represent in practically every instance averages of a considerable number of animals derived from different litters and fed during several seasons.

For a while photographs were made of each pig prior to slaughter. This procedure, however, did not serve the purpose. Thus, for example, No. 60 received skim milk, made a fair growth, was lean, angular and agile. No. 61 ate 2.5 percent milk, made much larger gains, was smooth, sturdy and capable of enduring a reasonable amount of hardship. No. 62 was fed 5 percent milk, gained rapidly at first, very slowly later, and with some difficulty was kept from dying outright. Yet the differences between these pigs thus diversely fed, all from the same litter, while fairly apparent are not made as obvious as was desired in the three photographs which appear opposite this page, although the camera was located identically in respect to the subject in each case. Hence it seemed better to photograph the animals in longitudinal section, as shown opposite this page as well as page 96.

The following table shows the general outcome of the skim, medium and rich milk trials. The pigs were fed from 46 to 51 days. The figures represent the averages of 16, 27, 15, and 6 pigs fed skim-milk, 2.5 percent and 5 percent milks and the standard ration.

TABLE IX—EFFECT OF FOOD ON COMPOSITION OF BODY GAIN

	Weight	Water	Dry matter	Ash	Protein	Fat	Milk sugar	Nutritive ratio of food	I-Ratio, protein to fat in gain	Average daily gain	Average daily dry matter gain
	Kilos	%	%	%	%	%	%	1:	I:	grams	grams
SIXTEEN PIGS FED SKIMMILK FOR 51 DAYS											
Food	343.1	90.62	9.38	0.74	3.82	0.04	4.78	1.28	...	...	...
Gain	14.05	64.39	35.61	4.06	16.97	14.52	...	...	0.86	276	98
TWENTY-SEVEN PIGS FED 2.5 PERCENT MILK FOR 48 DAYS											
Food	231.8	88.04	11.96	0.74	3.73	2.67	4.82	2.90	...	...	...
Gain	15.59	59.07	40.93	3.39	14.34	23.04	...	...	1.61	325	133
FIFTEEN PIGS FED FIVE PERCENT MILK FOR 46 DAYS											
Food	238.6	86.17	13.83	0.74	3.60	4.72	4.77	4.27	...	...	...
Gain	18.81	50.16	49.84	3.12	13.38	33.67	...	...	2.52	409	204
SIX PIGS FED A MILK AND GRAIN ("STANDARD") RATION FOR 50 DAYS											
Food	149.5	78.92	21.08	0.98	5.38	1.55	13.17*	3.11	...	...	...
Gain	18.53	65.81	34.19	2.23	11.71	18.98	...	...	1.62	371	127

*Includes grain carbohydrates.

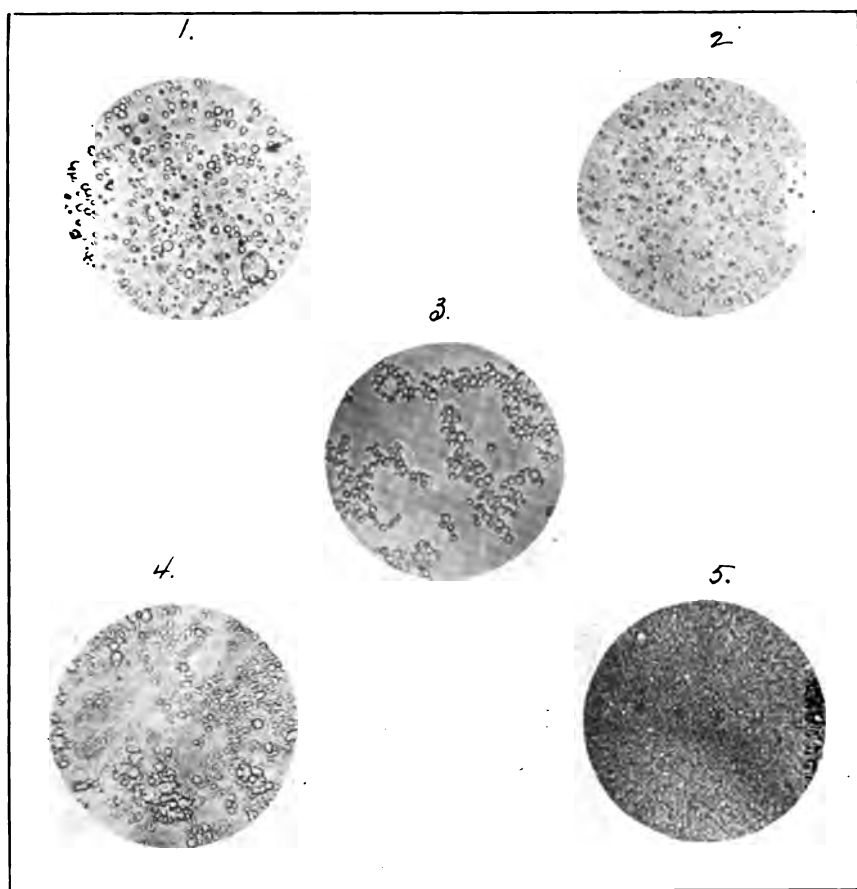


PLATE I. Photomicrographs of fat globules in milk.

1. Grade Jersey.

2. Grade Holstein.

3. Human.

4. Homogenized
at 85° F.

5. Homogenized
at 185° F.

(See pages 17, 56).



PLATE II. Pigs fed skim-, 2.5 and 5% fat milks. (See page 32).

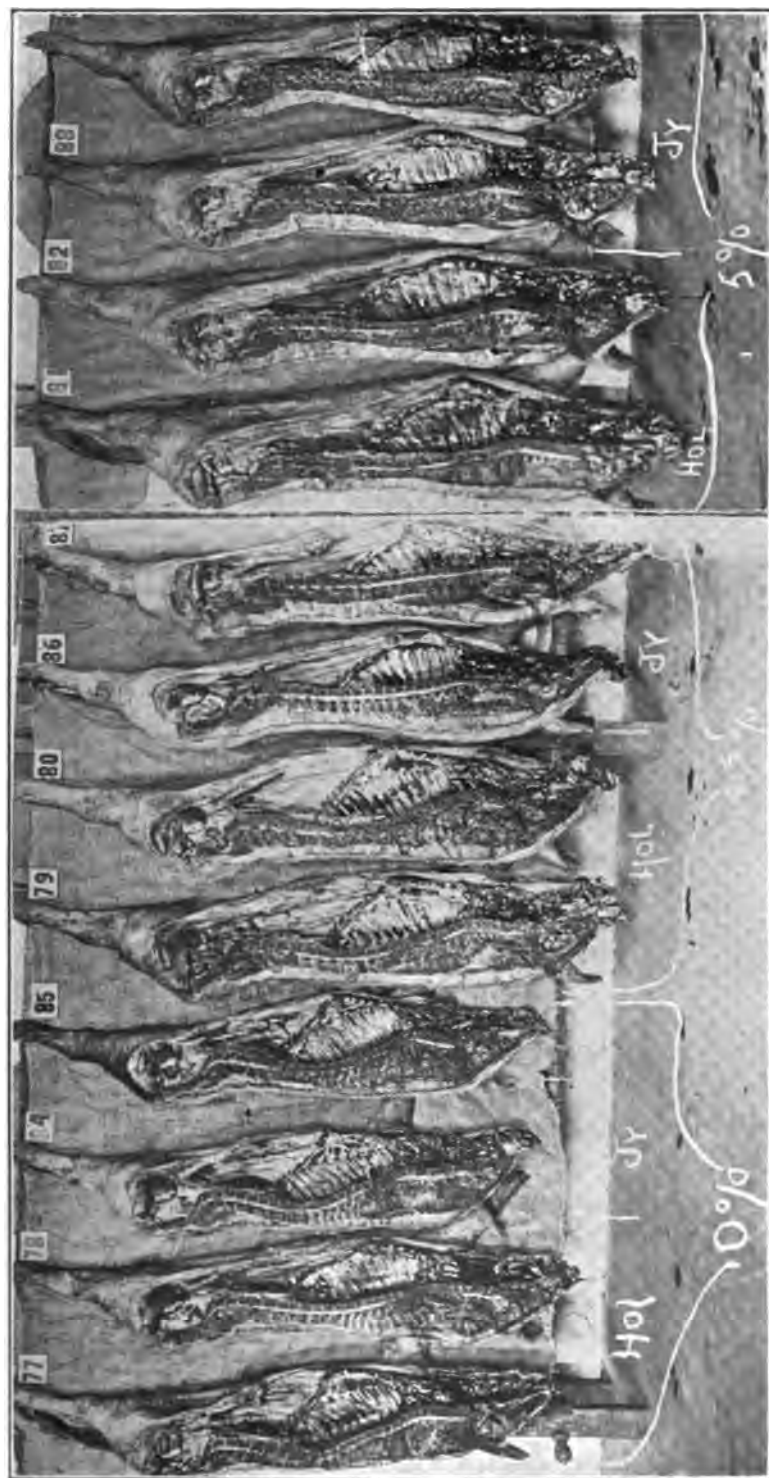


PLATE III. Cross sections of pigs fed grade Holstein or grade Jersey skim-, 2.5 and 5% fat milks. (See pages 31-47).

Normal milk

Homogenized milk

Homogenized skim milk and corn oil

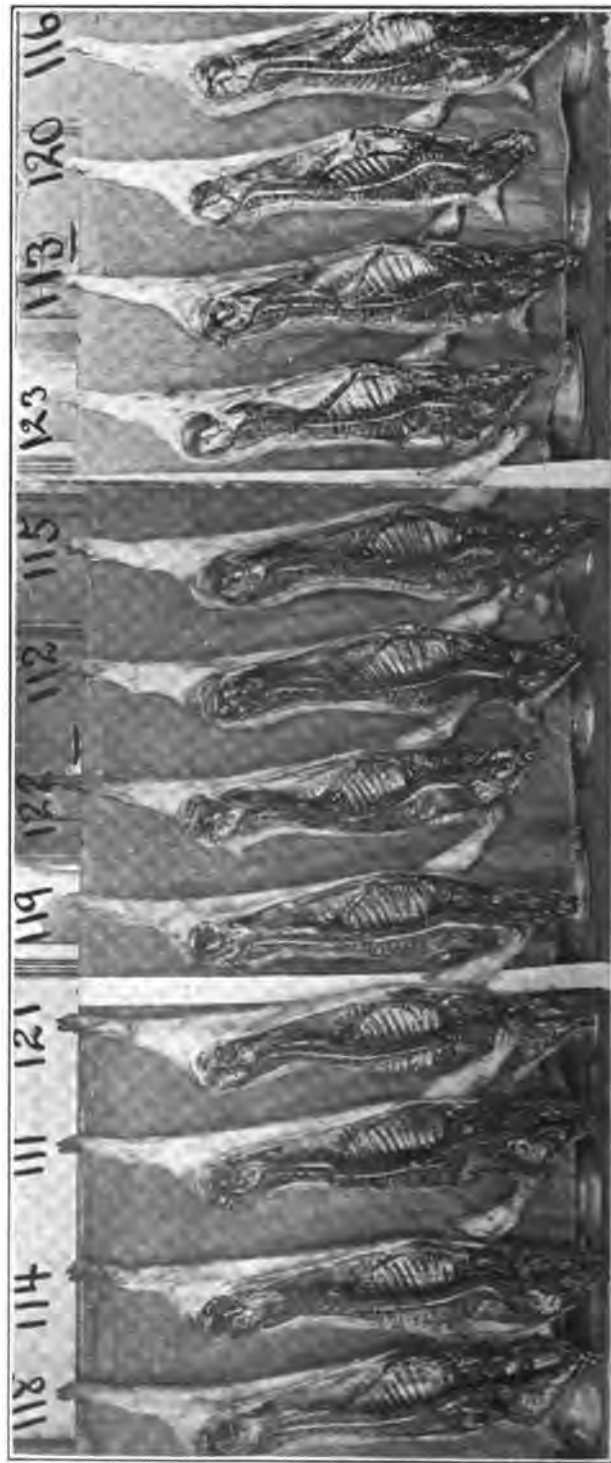


PLATE IV. Cross sections of pigs fed normal and homogenized milk and homogenized skim milk and corn oil. (See pages 55-59).

Normal

Homogenized



PLATE V. Curds from normal and homogenized milks. (See pages 56 and 57).

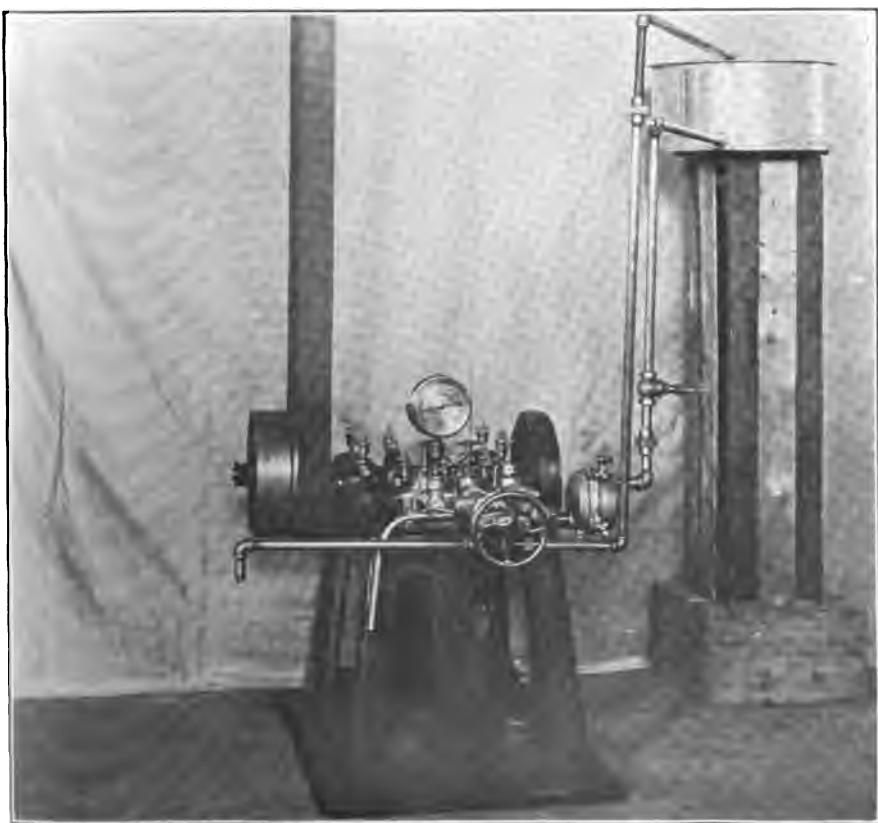


PLATE VI. Homogenizer. (See page 55).



PLATE VII. Cross sections of six pigs fed normal 3% milk, six fed unsweetened evaporated milk and six fed sweetened condensed milk. To the right hand three in each case calcium phosphate ($\text{Ca}_3\text{P}_2\text{O}_8$) was fed; to the left hand three in each case d. milk was fed. (See pages 69-79).

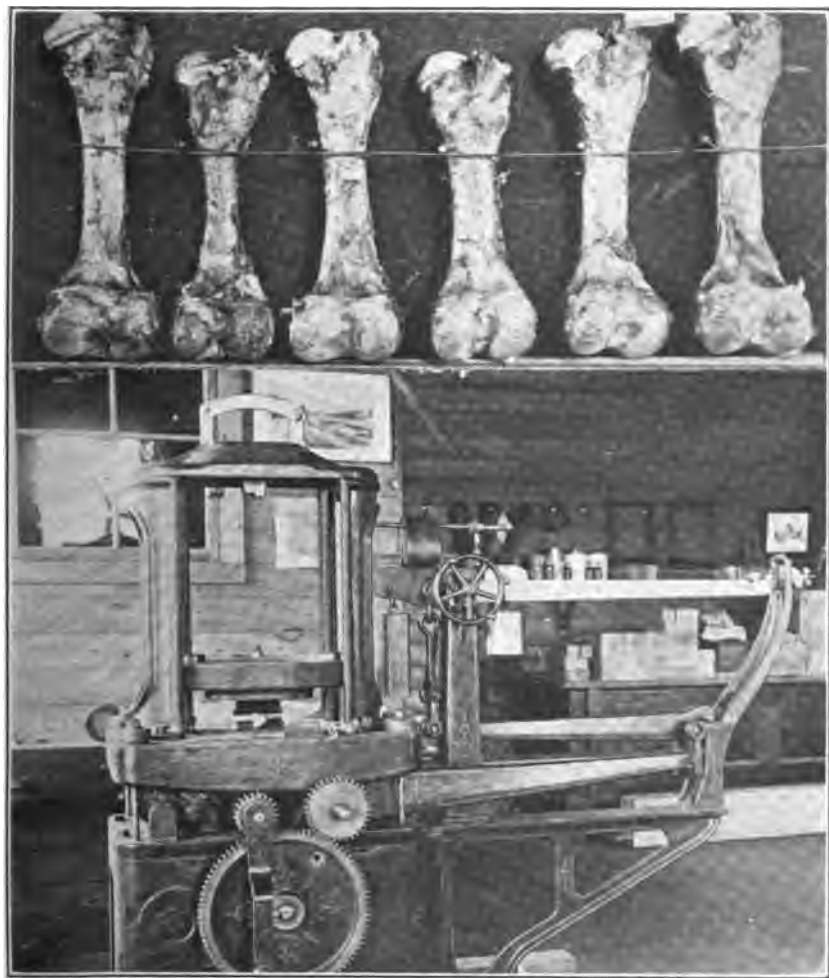


PLATE VIII. Typical femurs.
Breaking test machinery. (See pages 82-86).

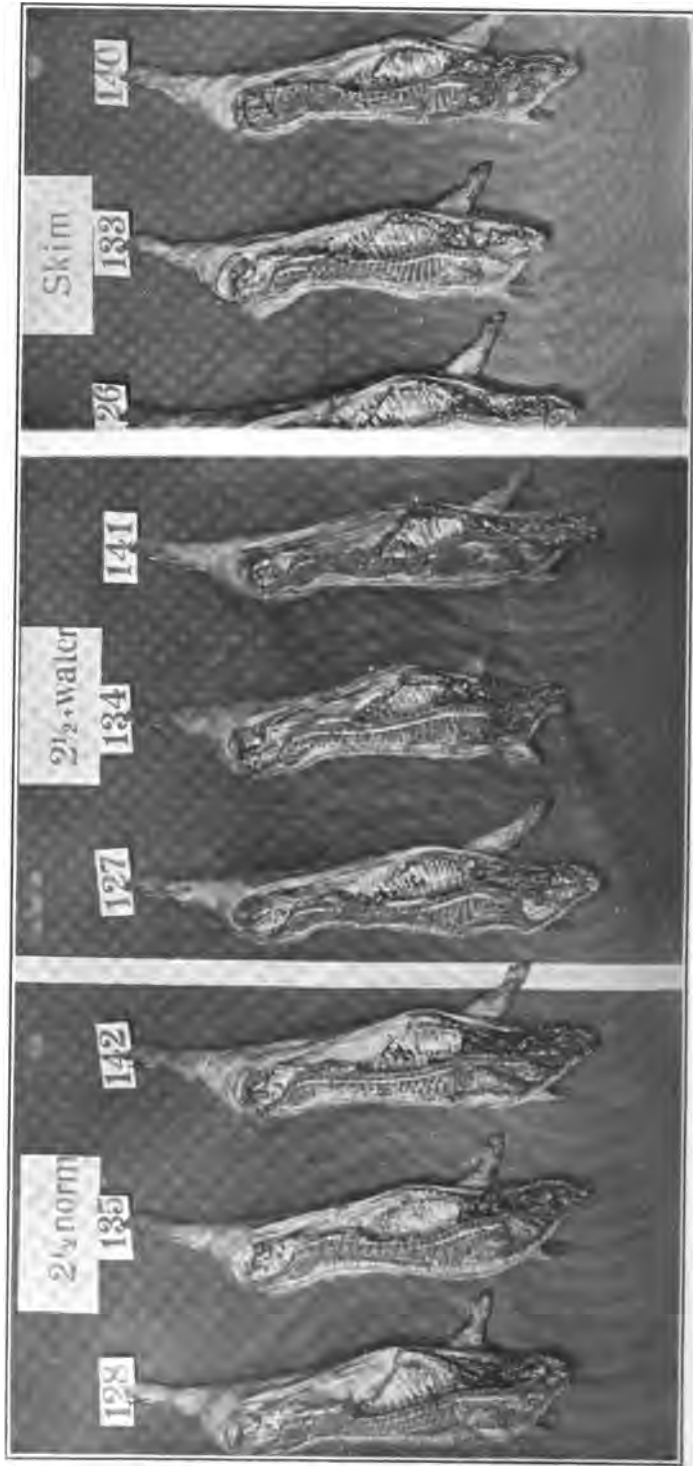


PLATE IX. Gross sections of pigs fed 2.5% normal milk, 2.5% milk diluted with water, and skim milk. (See pages 86-90).

The 16 pigs fed skimmilk for 51 days averaged to gain daily 276 grams, 98 grams of which was dry matter; the 27 fed 2.5 percent milk for 48 days gained daily 325 grams containing 133 grams of dry matter; and the 15 fed 5 percent milk for 46 days gained daily 409 grams containing 204 grams of dry matter. The average standard-fed pig fed for 50 days gained 371 grams daily containing 127 grams dry matter, approximating in this respect the record of the 2.5 percent group. The dry matter percentages in the body gains vary from 34.19 to 49.84, being least with the standard ration and greatest when 5 percent milk was fed. It is interesting to note that the bulkiest ration yielded the least body gain.

The skimmilk pigs laid on flesh rather than fat. The relativity of the protein and fat contents tells this story most clearly. The average standard pig with a low protein percentage in the gain (11.7) carried a 19 percent fat content and its protein to fat ratio was 1:1.62. Since the six pigs from three litters which constitute the standard were physically perfect animals throughout the feeding period, it seems safe to say that this 1:1.62 protein to fat ratio may be assumed to be approximately the desirable one in early life. The ratio which the skimmilk group displayed is a very different one—1:0.86. It resembles that of the young pigs when experimental feeding began. Clearly if the body of a three months old pig carries the same fat percentage as did its body when a month old, the total amount of fat in the body must have increased. Since the skimmilk used in these trials was essentially fat-free it seems fair to assume that the body fat thus stored was formed mainly from the milk sugar. The vigor of the skimmilk-fed animals was remarked at killing time, even by those unfamiliar with the nature of the trials or the differences in the rations fed.

The average data furnished by the 27 pigs fed 2.5 percent milk closely resemble the data secured with the six standard-fed pigs. The protein to fat ratios were identical. It should not be assumed on this account, however, that the 2.5 percent milk ration was of equal value to the standard ration.

The large deposition of fat which occurred when 5 percent milk was fed deserves special attention. The gain made contained 13.38 percent protein and 33.67 percent fat, a protein to fat ratio of 1:2.52, which is much wider than that obtained with the standard group. This high fat percentage is also exhibited in the dry matter column. The

body gain of the fat-fed pigs was half and half while that of the standard-fed group was one-third and two-thirds dry matter and water. The health of the fat-fed pigs was far from good. Serious digestive disturbances frequently occurred, they often appeared dull and logy and their vigor obviously was impaired.

This table portrays parallelisms. The composition of the body gain is determined by and follows the composition of the food. Sixteen normal pigs, fed for 51 days on a nearly fat-free ration with a nutritive ratio of 1 : 1.28, produced gain with a ratio of protein to fat of 1 : 0.86; 27 normal pigs fed for 48 days on a ration with a nutritive ratio of 1 : 2.90, produced gain with a ratio of protein to fat of 1 : 1.61; 15 normal pigs, fed for 46 days on a ration with a nutritive ratio of 1 : 4.27, produced gain with a protein to fat ratio of 1 : 2.52; while six pigs fed for 50 days on a ration thoroughly normal and well adapted to the growing of pigs and possessing an average nutritive ratio of 1 : 3.11, produced gain with a protein to fat ratio of 1 : 1.62.

It should be noted that whenever the quantity of fat in the animal body exceeded the quantity of protein by more than about 50 percent, the animal became sluggish, peevish, of low vitality and, though handsome, was physically abnormal.

The constancy with which change in the nutritive ratio of the food was reflected in modification of the proportion of muscular tissue to adipose tissue, was striking. This fact, when taken into account in connection with the observations recorded in the clinical data as set forth on pages 122 to 136, furnishes some of the most significant evidence which has come thus far to the attention of the writers and affords food for thought concerning prevailing methods of infant feeding.

The attention of those pediatricists who favor the use of excessively lean milk is called to the character of tissue produced by the skim-milk. In all cases where the quantity of body fat was less than the quantity of muscular tissue the pigs obviously were lean, angular and under-sized. The over-fat pigs were in a dangerous condition and the under-fat in an indifferent condition. The ideal was attained more nearly when milk with 2.5 percent fat and a nutritive ratio of about 1 : 3 was fed, which, it may be remarked parenthetically, is in entire accord with the experience of livestock men who grow young animals for profit. In this connection mention may be made again of the fact that the digestive disturbances arising when a high-fat ration was fed

were rectified by putting the animal on a skimmilk diet for a day or two.

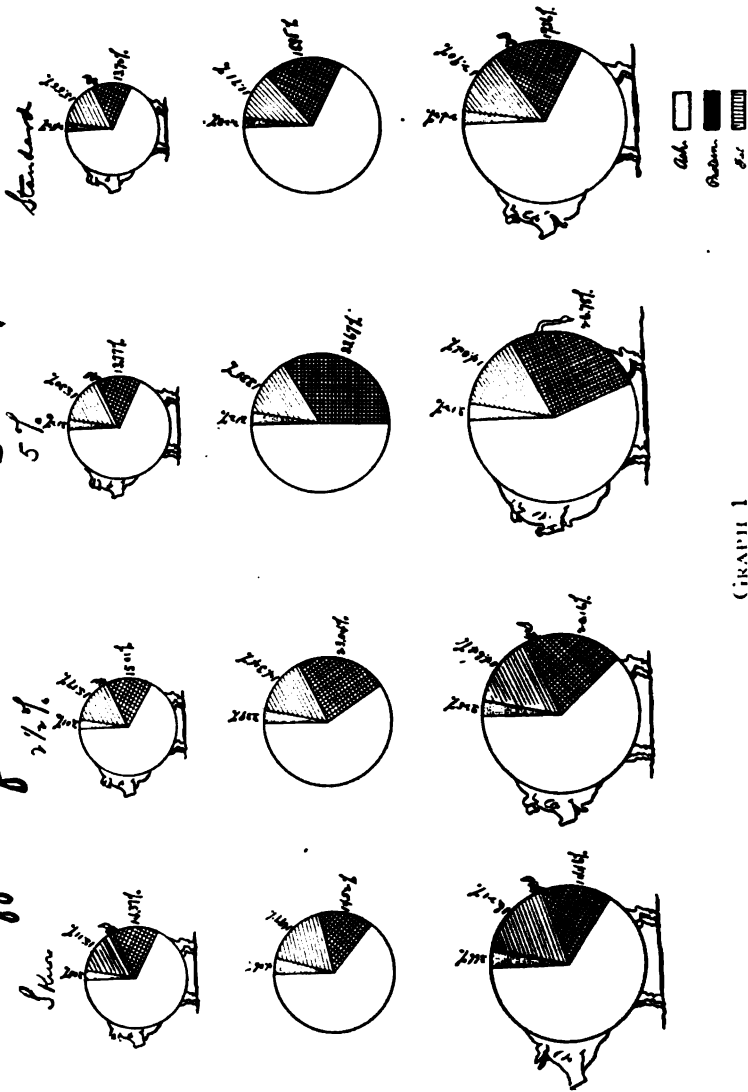
The food nutritive ratios in the several groups were, respectively, 1:1.28, 1:2.90, 1:4.27, and 1:3.11. The second and last produced a normal body growth, the first a muscular growth, the third a mass of fat. Had the nutritive ratio in the skimmilk group been slightly increased by the addition of from 0.5 to 1 percent of fat, doubtless fairly good animals would have been grown. A 5 percent fat ration may be adapted to the purpose of a full-grown, mature animal that one wishes to fatten, but it appears utterly unfitted to grow an animal in the formative period of its life.

Graph 1 shows the average composition of the check pigs killed at the outset of the trials, (upper horizontal column), of the gains, (middle horizontal column) and of the pigs when killed, (lower horizontal column). The pictures—if such they may be called—are drawn to scale. The left hand perpendicular column shows the average composition of the skimmilk group at start and finish, and the difference between the two is represented by the middle circle, which indicates the composition of the gain; the second perpendicular column affords similar information as to the animals fed 2.5 percent milk; the third perpendicular column depicts the history of the 5 percent fat-fed animals; while the righthand column illustrates that of the standard fed animals.

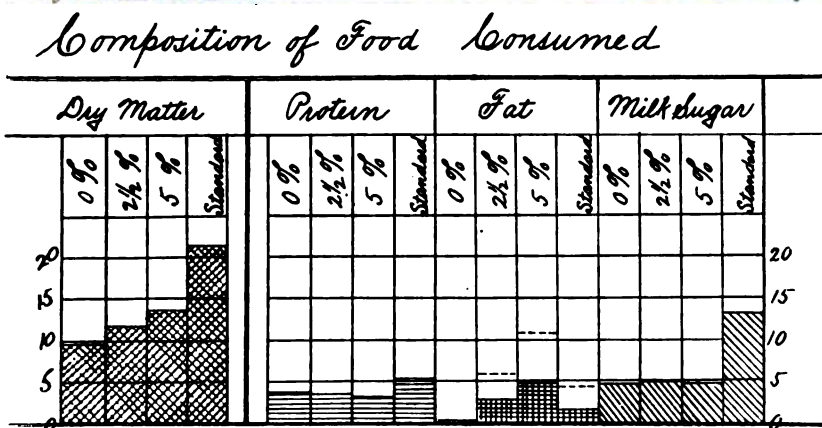
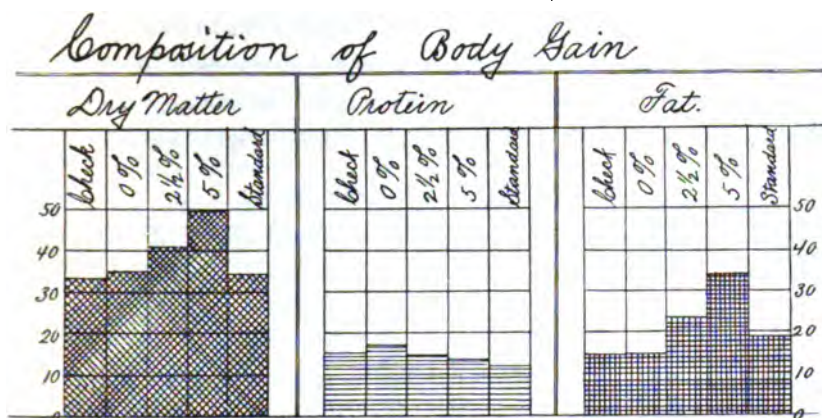
It should be remembered that all the pigs were on a par at the outset, that at the start the bodies of the four check pigs contained essentially uniform amounts of water, ash, protein and fat. This being the fact, it is clear that the extreme diversities in type manifested at slaughter may be ascribed to the varying amounts of fat which the pigs consumed.

The gains, or center circles, feature the points with which we are chiefly concerned. The gradual increase in body fat as more food fat is ingested is clearly indicated as one reads from left to right on the center circles, the percentages being 14.52, 23.04, 33.67 and 18.98.

Effect of Food on Body Composition.



GRAPH 1



GRAPH 2

The upper section of graph 2 shows the body composition of the check pig and the composition of the gain when the skimmilk, 2.5 percent, 5 percent and standard ratios were fed. Attention is called again to the large gain in dry matter, the relatively slight diminution in protein, and the large increase in body fat when 5 percent milk was fed. The increase of protein in the gain of the skimmilk-fed pigs, as has been mentioned previously, clearly is in evidence.

The lower section of graph 2 indicates the composition of the food. The increased amount of dry matter in the standard ration is of course due to the increase in protein and carbohydrates other than fat supplied by the grain adjunct.

AVERAGE GAIN PER WEEK

Table X sets forth the percentage gained each week by the several groups just discussed. The number of animals contributing to the averages and their fairly uniform initial weights should be noted

TABLE X. PERCENTAGE GAINS

Number of pigs	Initial weight kilos	Average 7 days	14 days	percentage 21 days	28 days	percentage 35 days	gains in 42 days	weight at 49 days	the end of 56 days	61 days
SKIMMILK-FED PIGS										
16	9.67	9	27	52	74	100	...	...	...	...
14	9.54	10	27	51	73	97	118	...	...	...
12	9.99	7	24	47	68	91	114	134	...	...
8	10.88	6	17	47	68	89	111	132	146	...
6	11.42	6	13	44	65	81	103	122	132	147
2.5 PERCENT MILK-FED PIGS										
27	8.76	11	33	56	83	111	...	...	...	...
23	8.91	11	31	53	80	108	141	...	...	...
22	9.01	10	29	51	77	104	133	169	...	...
7	11.50	10	34	63	95	117	148	180	196	...
6	11.84	10	33	62	94	113	144	174	187	206
5 PERCENT MILK-FED PIGS										
15	9.97	18	43	79	111	...	...	...	...	...
14	10.04	18	44	79	112	138	...	...	...	...
8	10.61	18	44	87	116	151	180	219	...	...
6	11.26	15	38	82	112	147	178	217	241	...
4	12.37	14	37	85	113	144	167	203	214	225
STANDARD-FED PIGS										
6	8.26	10	21	47	86	129	168	224	...	...

The 16 pigs in the skimmilk-fed group on the average had gained nine percent of their initial weight (9.67 kilos) at the end of seven days feeding, 27 percent after 14 days feeding, etc. and they doubled their weight in 35 days. Fourteen of these 16 pigs fed for 42 days gained 118 percent of their initial weight; 12 of the 16 fed for 49 days gained 134 percent; eight fed 56 days, 146 percent; and six of these 16 pigs, whose initial weight averaged 11.42 kilos, gained 147 percent after 61 days of feeding.

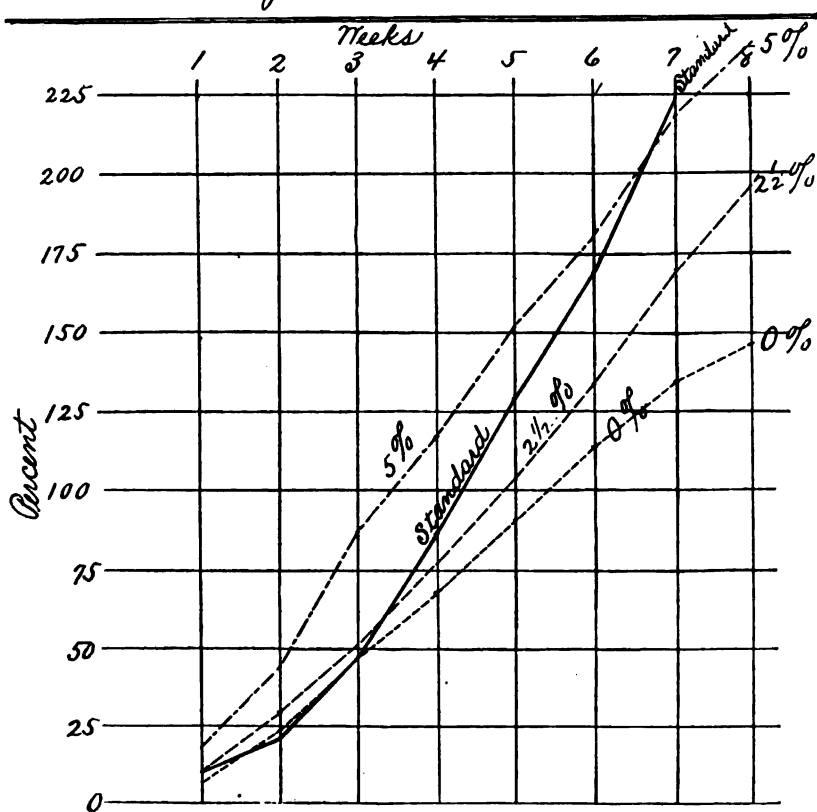
The 27 pigs fed on 2.5 percent milk on the average doubled in weight in 32 days, while six fed for 61 days increased over 200 percent in weight.

The 5 percent fat-fed pigs made more rapid gains. Fifteen fed for 28 days on the average doubled in weight in 26 days, while four members of this group doubled their weight in 25 days and, after 61 days of feeding, had increased in weight 225 percent.

The record of the standard-fed pig, representing the average of six normally fed animals, is included in this table for purposes of comparison. It is seen that the weight was doubled in about 31 days, in this respect duplicating the performance of the 2.5 percent fat-fed group, and that after only 50 days of feeding the record made by the four pigs in the 5 percent group that had been fed for 61 days was equalled. Moreover every one of the standard animals was in prime condition, whereas the 5 percent fat-fed animals were far from being vigorous specimens, owing to the large accumulation of fat throughout their bodies (see graphs 1 and 2 and table IX).

While a rapid increase in weight usually means economy in gain, it does not follow necessarily that such an increment is desirable from the standpoint of the well being of the animal. Considered alone, mere gain in weight is a poor criterion by which to judge the value of a food when fed to the young of any species.

Average Gain per Week.



GRAPH 3

The average weekly gain of the several groups under discussion is again shown in graph 3. The 5 percent-fat pigs led for nearly seven weeks when they were passed by those fed the standard ration. All those fed milk alone gradually fell off during the eighth week. The pigs in the 5 percent fat-fed group should not be deemed superior simply because of their early and rapid gains in weight. Their hospital records and seriously impaired vitalities should be remembered if one is tempted to make use of their records in formulating dietaries intended to induce normal and desirable body gains in human or brute creation.

GROWTH OF YOUNG PIGS

Many of the results thus far discussed, together with other calculations of interest dealing with the life history of the several groups under investigation, have been summarized in table XI.

TABLE XI. GROWTH OF YOUNG PIGS

	Skim-milk	2.5 % milk	5 % milk	Standard
1 Initial weight, kilos	9.67	8.76	9.97	8.26
2 Final weights, kilos	23.75	24.35	28.78	26.79
3 Gain, kilos	14.05	15.59	18.81	18.53
4 Percentage gain	145	178	189	224
5 Available Calories fed	116100	131400	176420	115900
6 Total gain per kilo of food consumed (grams)	41	67	79	124
7 Dry matter gained per kilo dry matter consumed (grams)	155	230	284	224
8 Gain per 1000 Calories consumed (grams)	121	119	107	100
9 Gain in dry matter per 1000 Calories consumed (grams)	43	49	53	55
10 Calories retained as growth : Total	246	322	390	357
per 1000 Calories fed : as protein	84	70	59	77
: as fat	162	252	331	280
11 Starch equivalent or Calorie ratio, 1: ...	4.27	3.27	2.70	2.95
12 Ratio protein fat in gain, 1:	0.86	1.61	2.52	1.62
13 Nutritive ratio of food, 1:	1.28	2.90	4.27	3.11

Here, in lines one to four, are recorded the initial and final weights and the gains expressed as kilos and as percentages; and in lines five to seven are shown the available food Calories consumed, the total gain per kilo of food consumed and the dry matter gained for every kilo of dry matter consumed. As the fat content of the milk increased the percentage gains and gains per kilo of food and of dry matter also increased; and so did food consumption increase and in a measure proportional to the weight gains made by the milk-fed pigs; but when grain was added to the ration, greater economy of production followed as a matter of course.

Interpreting the next three lines (8, 9 and 10), which display total and dry matter gains per 1,000 Calories and Calorie retention as growth, it is to be observed that the skimmilk-fed pigs gained 121 grams per 1,000 Calories consumed; that 43 grams of this gain were dry matter (ash, protein and fat); and that 246 Calories were retained for growth, 84 in the form of protein and 162 as fat. The pigs fed 2.5 percent milk gained 119 grams, 49 of which were dry matter containing 322 Calories, 70 as protein and 252 as fat. The animals fed 5 percent milk gained 107 grams, 53 grams of which were dry matter, equivalent to 390 Calories, 59 as protein and 331 as fat—a large deposition of fat. The standard ration, for every 1,000 Calories consumed, produced a total gain of 160 grams with 55 grams of dry substance, which contained 357 Calories, 77 as protein and 280 as fat, a distribution of protein and fat in the gain in live weight quite similar to that secured when 2.5 percent milk was fed, although the total and dry matter gains were larger. The statement as to the Calories retained as growth for each 1,000 physiologically available (95 percent digestibility assumed) Calories fed, and the subdivision of the total into protein and fat (line 10), not only enables a direct comparison as to utilization of food for growth, but also indicates the relative amounts of energy retained in the body gain as protein and as fat. It shows clearly that a high fat content in a food may produce a large gain in weight and in Calorie retention and a low starch equivalent (line 11), that, in other words, it may be an economical food. It does not mean, however, that a food with a high fat content necessarily is the best for growing animals. The protein to fat ratio (line 12) probably should approximate 1 : 1.6 where health and bodily strength are the prime essentials. The economy of body gain is not the issue, but, rather, the quality of body tissue which may be produced irrespective of cost.

The greater physiological economy of the richer ration is shown further by the fact that it required 4.27 units starch equivalent or Calorie ratio to produce a unit in gain on skimmilk, 3.27 units when the 2.5 percent milk was fed, only 2.70 units when 5 percent milk was used, and 2.95 units when the standard ration was fed. This is due to the fact that fat has 2.25 times the calorific value of milk sugar and that its moderate increase greatly augments the possibilities of storage. It is also due to the fact that food fats are resorbed easily and deposited in the body without apparent material change, whereas glandular and intestinal work must be done upon sugar to convert it from the simple carbohydrate molecule into the more complex fat.

A study of the protein to fat ratio in the gains (line 12) indicates clearly that the fat-milk-fed animals gained primarily in fat, while the skimmilk group deposited a larger proportion of the energy in their food in the form of muscular tissue.

The statement as to the nutritive ratios of the several foods, (line 13) is significant. In the judgment of the writers the ratio best suited to the growth of young pigs approximates 1 : 3. If only milk is fed, its fat percentage at most should exceed but slightly the protein percentage, and it were better if it were no larger.

UTILIZATION OF FOOD CONSUMED BY YOUNG GROWING PIGS

The following table shows the percentage utilization of physiologically available Calories in the food consumed, and also, incidentally, the percentage of ash fed that was utilized for gain.

TABLE XII. PERCENTAGE UTILIZATION OF PHYSIOLOGICALLY AVAILABLE CALORIES IN FOOD

	Skimmilk		2.5% milk		5% milk		Standard	
	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain
Total Calories	18	25	15	32	13	39	19	36
Protein Calories	7	19	10	27	11	31	13	32
Milk sugar and fat Calories.	27	29	17	34	13	41	21	37
Ash	..	22	..	31	..	33	..	28

These calculations are based on an assumed maintenance requirement (page 14) and on the known Calories in the gain compared with the known amount of protein, milk sugar and fat Calories fed.¹

CALCULATION OF MAINTENANCE REQUIREMENT FOR PIGS

¹ This calculation is based on Dietrich's maintenance factor [Ill. Sta. Circ. 126 (1907)], 0.1 protein, 0.4 carbohydrates, 0.04 fat pounds per day for 100 pounds live-weight. This is equivalent to 25 Calories divided as follows, protein 4 Calories, carbohydrates 17 Calories, and fat 4 Calories per day per kilo of live weight.

To illustrate we will apply these figures to the average representing the standard pigs.

Initial weight.....8.256 kilos $\times$ 25 = 206 Calories (A)

Weight when killed26.785 kilos $\times$ 25 = 670 Calories (L)

The feeding period lasted 50 days. Let S = total Calories required for maintenance and N = number of days fed.

Then $\frac{N}{2} (A + L) = S$; or, in the case in hand, $\frac{50}{2} (206 + 670) = 21,900$

21,900 Calories are required for maintenance in this suppositious case. This may be divided into protein, carbohydrate and fat Calories in the proportions indicated above.

CALCULATION OF MAINTENANCE REQUIREMENT FOR PIGS

In considering a percentage statement of Calories retained for growth it should be remembered that these figures are dependent directly on the amount of food Calories consumed, and that any excess eaten over the amount needed for maintenance and growth lowers the percentage amount of Calories retained. The data in this table make it clear that the animals were well fed, and possibly overfed, and that their Calorie consumption was ample.

Considerations of food economy are indicated by the percentage amount of total Calories retained as growth in the several groups. The skimmilk pigs saved in their tissue 25 percent of all they received, the medium milk group 32 percent, and the rich-milk group 39 percent, while the standard-fed pigs conserved 36 percent of the total food fed. The form in which the food units were deposited, whether as muscular or fatty tissue, is set forth in the table.

The protein utilizations in the form of gain in the four groups were 19, 27, 31 and 32 percents respectively. The 19 percent acquired by the skimmilk group was sufficient to produce a very muscular tissue, as already has been indicated.

The milk sugar and fat were utilized as shown in the third line, 29, 34, 41 and 37 percents being retained for growth. The 29 percent utilization by the skimmilk-fed pigs represents the efficiency of milk sugar fed in the absence of fat. There seems reason to believe that pigs fed 2.5 percent and 5 percent milks, which stored respectively 34 and 41 percent of their carbohydrates, made free use of the fat in their ration, while a liberal usage was made of carbohydrates other than fat when the standard ration which contained a relatively small amount of fat was fed.

The amount of ash stored in the body would seem to indicate that all the rations contained plenty of ash. However, when more was supplied the pigs apparently made good use of it.

It may be of further interest to consider the percentage excess of food over maintenance utilized for growth. This table is of value primarily as indicating what may be expected of animals in the way of energy conservation.

TABLE XIII—PERCENTAGE EXCESS FOOD OVER MAINTENANCE UTILIZED FOR GROWTH

	Skim- milk	2.5 % milk	5 % milk	Stand- ard
Total	30	38	45	44
Protein	20	30	35	37
Milk sugar and fat	40	41	47	47

The several figures in this table are predicated upon the validity of the maintenance requirement assumed as suitable for growing pigs as set forth on page 14. The milk-fed groups utilized 30, 38 and 45 percents, while that fed the standard ration resembled in this respect the 5 percent group, whereas in other respects the standard and the 2.5 percent groups have more nearly approached each other. However, in previous discussion it has been shown that the results as to body composition were far from being identical, the standard ration producing ideal animals while the 5 percent rations induced a condition of obesity and ill health.

These points can be illustrated again by making a direct comparison between the Calories in one kilo of gain and the Calories in one kilo of food consumed, tables XIV and XV.

TABLE XIV—CALORIES IN ONE KILO OF GAIN

	Skim-milk	2.5 % milk	5 % milk	Standard
Protein	695	588	549	480
Fat	1340	2126	3106	1750
Total	2035	2714	3655	2230
Ash (grams)	41	34	31	22

TABLE XV. CALORIES (AVAILABLE) IN ONE KILO OF FOOD CONSUMED

	Skim-milk	2.5 % milk	5 % milk	Standard
Protein	149	145	140	188
Milk sugar	186	188	186	463
Fat	4	234	413	124
Total	339	567	739	775
Ash (grams)	7.4	7.4	7.4	9.8

These tables show that the standard ration, containing 188 Calories per kilo as protein, 463 as milk sugar and other carbohydrates and only 124 Calories as fat, produced a body growth containing 480 Calories per kilo as protein and 1,750 as fat. The animals were vigorous. The 5 percent milk-fed animals received 140 Calories as protein, 186 as milk sugar, and 413 as fat, which yielded a growth in every kilo of which were found 549 protein and 3,106 fat Calories, a combination not suited to the purposes of a young and growing animal or conducive to its health and vigor in later life.

A clearer understanding of this matter may be obtained by calculating from tables XIV and XV, figuring the protein, carbohydrate and fat data on a unity basis, calling protein 1. Thus we have:

TABLE XVI. RATIOS

	In food consumed			In gain	
	Protein	Milk sugar	Fat	Protein	Fat
Skim milk	1	: 1.3	: 0	1	: 1.9
2.5 percent milk	1	: 1.3	: 1.6	1	: 3.6
5 percent milk	1	: 1.3	: 2.9	1	: 5.7
Standard	1	: 2.4	: 0.7	1	: 3.6

This statement represents simply a nutritive ratio comparison. The milk sugar figures in the "food consumed" column are uniform on the strictly milk diet; the differences occur in the fat data. The 5 percent milk diet (ratio 1:1.3:2.9) produced a large but unbalanced gain with a ratio of 1:5:7. The 2.5 percent milk ration, (ratio 1:1.3:1.6) produced a similar quality of tissue to that furnished by the standard ration (ratio 1:2.4:0.7.) The differences between these two are not of nutritive ratio but rather of the distribution of the energy units.

The writers hold that the bearing of the nutritive ratio of a food for the young on the formation of body tissue is important and that in the feeding of the human infant proper relations between the milk sugar and fat contents of its ration as well as the proper proportioning of these to the protein contents are vital matters.

It was observed that a few of the pigs fed the skim milk diet increased in weight much less rapidly than did their mates, and that, when slaughtered, their carcasses contained much water and relatively little dry matter, which, however, was very rich in protein. Their bodies contained not only a smaller percentage of fat when killed than was present at the start, but the actual amount of fat present was less after several weeks feeding. Most of the pigs receiving skim milk for their sole food gained in fat. Evidently those that lost fat were unable properly to utilize milk sugar and, instead of consuming the energy of the ingested protein in part for maintenance purposes, thus utilized a part of the previously stored fat while storing protein. These animals, as has been pointed out, doubtless suffered from malnutrition. The analytical data secured in these cases are printed in the appendix but have not been used in this bulletin, remaining on hand as a basis for further discussion.

VITALITY

Although the amount of food required to produce a unit amount of tissue in an animal is a measure of its efficiency in respect to the

particular matter now under consideration, the invisible, imponderable quality known as "vitality" is of equal if not greater importance than either commercial or physiological economy of production.

Early in the series it became evident that some of the rations produced sluggish and weak animals while others produced much more vigorous individuals. Even when all the pigs received earth as intestinal ballast and, consequently, remained in good health, it was seen readily that the high-fat rations produced animals of relatively low vitality. This point is illustrated by the five percent-milk-fed pigs Nos. 35 and 36. The former died at once when accidentally, but lightly, struck by a small wooden rack; and the latter succumbed from fright while being transported a distance of some 50 rods to the slaughter laboratory (see appendix, page 125). Furthermore it was observed at the time of slaughter that high-fat-fed animals always succumbed to chloroform more quickly than did their mates fed on skim- and medium-fat milk. So marked were these differences that the laboratory assistants soon were able correctly to classify the animals by their resistance to the anaesthetic.

The clinical observations were consistent throughout. The pigs fed low fat and relatively high protein rations uniformly manifested the greater vitality.

CONCLUSIONS

1. The character of the tissue produced is determined by and closely parallels the chemical composition of the food consumed.

2. A ration supplying a large amount of protein in proportion to the total energy available (e. g. skimmilk) produced sturdy, agile, but rough and undersized pigs.

3. Milk carrying a medium fat content (2.5 percent) and, hence, less protein in proportion to the total units of energy available than does skimmilk, produced healthy, "growthy," active, yet smooth and fair sized pigs.

4. Milk containing a large quantity of fat (5 percent) in proportion to protein, produced a rapid increase in weight and physiologically economical gains; but the pigs were in a dangerously over-fat condition and betrayed peevishness and low vitality.

5. The body of the young pig and, if the results of these trials are applicable to human infant feeding¹, that of the human young, should not contain much more than approximately 1.6 parts of fat for

¹ In this connection compare pages 21-23, 27-28.

every one part of protein. If a ration carrying a nutritive ratio of about 1:3 is used, a 1:1.6 result, or an approximation to such a result may be expected.

VIII. SMALL AND LARGE FAT GLOBULES

Turning now to another of the initial problems of this series, namely, the relative nutritive values of Holstein and Jersey milks as food for infant animals, let us consider the effect on the body gain of the ingestion of different sizes of fat globules. The fat globules in Holstein milk average smaller than do those in Jersey milk, the relative average diameters being 1-12,000 inch in the Holstein and 1-9,000 inch in the Jersey, an average difference of 1-36,000 inch.

A summary of the findings appears in tables XVII to XXIV. These tables resemble in their general character the similar tables in the preceding section and they occur in the same order.

TABLE XVII—EFFECT OF FOOD ON COMPOSITION OF BODY GAIN

	Weight	Water	Dry matter	Ash	Protein	Fat	Milk sugar	Nutritive ratio of food	Ratio, protein to fat in gain	Average daily gain	Average daily dry matter gain
	Kilos	%	%	%	%	%	%	1:	1:	grams	grams
SIX PIGS FED HOLSTEIN AND SIX JERSEY SKIMMILKS FOR 51 DAYS											
Food H.....	345.5	90.90	9.10	0.69	3.54	0.05	4.82	1.40	...	...	...
Food J.....	370.7	90.43	9.57	0.73	4.00	0.04	4.80	1.22	...	...	...
Gain H.....	14.16	64.92	35.08	4.22	17.38	13.74	...	...	0.79	278	97
Gain J.....	15.76	62.66	37.34	3.98	17.02	16.34	...	...	0.96	309	115
FIVE PIGS FED HOLSTEIN AND SEVEN JERSEY 2.5 PERCENT MILKS FOR 48 DAYS											
Food H.....	333.7	88.45	11.55	0.73	3.53	2.42	4.87	2.93	...	...	...
Food J.....	308.9	88.10	11.90	0.73	3.84	2.60	4.73	2.76	...	...	...
Gain H.....	20.69	56.10	43.90	3.40	14.64	26.01	...	...	1.78	390	171
Gain J.....	18.39	51.74	48.26	3.31	13.97	30.91	...	...	2.21	375	181
SIX PIGS FED HOLSTEIN AND SIX JERSEY 5 PERCENT MILKS FOR 46 DAYS											
Food H.....	270.0	86.90	13.10	0.71	3.36	4.24	4.79	4.26	...	...	...
Food J.....	224.9	85.61	14.39	0.73	3.83	4.99	4.84	4.19	...	...	...
Gain H.....	19.94	47.75	52.25	3.22	13.67	35.76	...	...	2.62	424	222
Gain J.....	19.05	51.20	48.80	2.99	13.16	33.26	...	...	2.53	405	198

It is, in a sense, somewhat of an anomaly to include in a feeding trial designed to determine the relative values of large and of small fat globules a comparative trial of skimmilks which, theoretically, are nearly fat-free. However, in view of the fact that the results might

turn upon the effects of the feeding of solids-not-fat from the one or the other source, it seemed desirable to feed these skimmilks as a check, as it were, upon the trials in which the whole milks were fed. Hence their inclusion and the following discussion.

When Holstein and Jersey skimmilks were compared, 12 pigs, six on each milk, were fed for 51 days. Although each ration was essentially fat-free, the group fed Jersey skinmilk produced a larger gross gain than did the group fed Holstein skimmilk, one furthermore which was materially richer in fat. Although the Jersey skimmilk ration carried 0.5 percent more protein, the protein content of the body gain of the animals fed upon it was somewhat less than that of the group fed Holstein milk, indicating a sufficiency of protein in both cases. The dry matter in the gain made by the Jersey group exceeds somewhat that made by the Holstein group, the increase paralleling closely the increase in fat percentage. The body fat necessarily was derived largely from the milk sugar. The milk sugar contents of the two rations were identical, but the Jersey group ate seven percent more food than did its competitor. The ratios of protein to fat in the gains are significant—Holstein skimmilk 1: 0.79, Jersey skimmilk 1: 0.96—despite the narrower nutritive ratio of the latter diet.

While the composition of the gains produced by skimmilk from Holstein and from Jersey sources were not particularly unlike, the latter seemed to produce usually, but not always, the better animal. (Numbers 77 and 78, Holstein, Nos. 84 and 85, Jersey, page 127). The Jersey skimmilk carried 9.57 percent of total solids and the Holstein only 9.10 percent, and, presumably on this account, the pigs in the Jersey-fed group usually grew a little more rapidly and somewhat more economically. Rapidity and economy of growth, however were not the prime issue, but the effect, if any, on the quality of the growth of the ingestion of fat globules of different sizes.

The fat content of the gain made by the five pigs fed 2.5 percent Jersey milk during 48 days as compared with that in the gain made by the seven fed 2.5 percent Holstein milk for the same length of time, was notably larger. The nutritive ratio of the Jersey ration was slightly narrower than that of the Holstein ration (1: 2.93 and 1: 2.76) while the ratio of protein to fat in the body gain was considerably larger (1: 2.21 and 1: 1.78). The standard-fed animals and the average of all those fed 2.5 percent milk, it will be remembered, showed a protein to fat ratio in the body gain of 1: 1.62, a lower figure than was secured with the dozen pigs used in these trials.

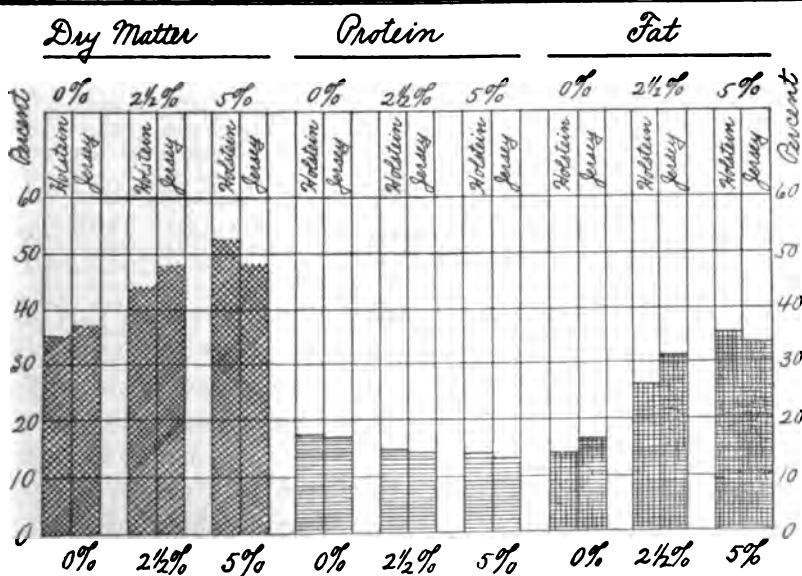
While the body gain of the Holstein-fed pigs contained more protein and less fat than that of the pigs which ate Jersey milk, both lots were satisfactory as viewed from the standpoint of stamina and thrift, and there was little visible difference between them.

When five percent milks of Holstein and Jersey origin were fed for 46 days to a dozen pigs, the results attained with both groups were quite uniform as regards the protein to fat ratios; but in general the outcome was the reverse of what was secured when skim- or low-fat milks were fed. The results, which seem slightly to favor the Holstein milk, were less marked than those secured when 2.5 percent milk was fed.

Through a regrettable error in the standardization calculation the group fed Holstein milk received but 4.25 percent fat in their ration instead of 5 percent. It may be that the higher fat percentage actually furnished to the group fed Jersey milk is responsible for the somewhat untoward result secured with these six animals. The quantity of the fat fed in each case exceeded what thrifty animals should consume.

Graph 4 displays the character of the tissue secured when milks of Holstein and Jersey origin were fed. That the dry matter and fat increased when skim- and 2.5 percent milks of Jersey origin were fed and decreased when rich milk of Jersey origin were fed were

Holstein vs Jersey. Composition of Gain. 0% 2½% 5% Milk



GRAPH 4

evident facts, as were, also, the protein differences. In view of the slight differences betrayed in these trials, it would seem that the size of the fat globules in milk cannot be considered an important factor.

Table XVIII shows the percentage gain in weight made at weekly intervals during the feeding periods wherein skim-, 2.5 and 5 percent milks of Holstein and Jersey origin were used.

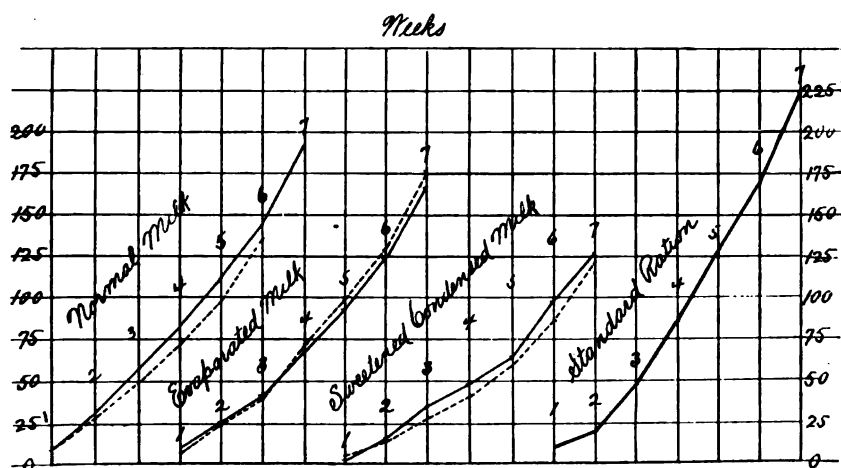
TABLE XVIII—PERCENTAGE GAINS

Number of pigs	Initial weight kilos	Average	percentage	gains	in weight	at the end of				
		7	14	21	28	35	42	49	56	60
days	days	days	days	days	days	days	days	days	days	days
HOLSTEIN SKIMMILK										
6	10.42	7	22	47	66	85	...	...	...	...
5	10.44	7	22	46	65	83	108	...	...	...
4	11.97	7	18	41	57	74	100	116	128	...
3	12.82	7	16	38	53	68	95	109	117	133
JERSEY SKIMMILK										
6	9.88	9	31	60	86	111	...	...	...	...
5	9.70	10	32	60	86	110	125	...	...	...
4	10.05	7	27	55	81	104	123	150	167	...
3	10.37	7	24	51	78	96	113	137	150	163
HOLSTEIN 2.5 PERCENT MILK										
5	10.51	12	35	69	103	126	...	...	...	...
4	11.07	10	33	66	105	123	153	...	...	...
3	12.48	8	26	60	90	104	133	161	174	191
JERSEY 2.5 PERCENT MILK										
7	9.35	12	43	72	101	128	...	...	...	...
4	10.77	12	39	66	98	128	162	196	214	...
3	11.20	13	39	65	98	123	158	188	200	222
HOLSTEIN 5 PERCENT MILK										
6	10.51	15	38	71	107	127	...	...	...	...
3	11.69	13	34	70	107	139	171	214	237	...
2	13.06	12	32	71	109	138	164	204	216	235
JERSEY 5 PERCENT MILK										
6	10.01	17	43	80	111	141	...	...	...	...
3	10.82	17	42	82	117	155	184	221	246	...
2	11.69	15	41	82	117	151	169	204	212	213

The Jersey skimmilk-fed animals made increased gains over the Holstein group throughout the feeding period. When 2.5 percent milk was used, the Jersey-fed group led for three weeks, when it was passed by the Holstein-fed group, which in its turn was passed at the end of six weeks feeding. The Jersey-fed group receiving rich milk kept consistently in the front for seven weeks, though by a narrow margin. These gains are well shown in the following graph, wherein the slightest predominance of the Jersey milk when skim- and rich milks were

fed and the essentially identical outcome when medium grade milk was used are made manifest.

Average Gain per Week
Normal, Evaporated, Sweetened Condensed Milk and Standard



GRAPH 5

TABLE XIX. GROWTH OF YOUNG PIGS

	Holstein skimmilk	Jersey skimmilk	Holstein 2.5%	Jersey 2.5%	Holstein 5%	Jersey 5%
1 Initial weights, kilos....	10.42	9.88	10.51	9.35	10.51	10.01
2 Final weights, kilos....	24.58	25.64	30.80	27.74	30.45	29.06
3 Gain, kilos	14.16	15.76	20.29	18.39	19.94	19.05
4 Percentage gain.....	136	160	193	197	190	190
5 Available Calories fed* ..	1170*	1284*	1804*	1741*	1857*	1743*
6 Gain per kilo of food....	40	43	61	60	74	85
7 Dry matter gained per kilo dry matter consumed..	154	160	231	241	295	287
8 Gain per 1000 Calories..	121	123	112	106	107	109
9 Dry matter gained per kilo dry matter consumed ..	43	46	49	51	56	53
10 Calories re- : tained as : Total	239	271	337	362	415	394
growth per : Protein ..	86	86	68	61	60	59
1000 Calo- : Fat	153	185	269	301	355	335
ries fed : 11 Starch equivalent 1 : ...	4.40	3.88	3.12	2.91	2.54	2.67
12 Ratio protein to fat in gain, 1 :	0.79	0.96	1.78	2.21	2.53	2.53
13 Nutritive ratio, food, 1 :	1.40	1.22	2.93	2.76	4.26	4.19

* + 100. I. e., 1170 = 117,000. (Condensation in order to print a perpendicular table).

Turning now to a study of the efficiency of the food consumed, it will be seen in table XIX that the food of Holstein origin (line 11) produced a unit of gain in the different groups for every 4.40, 3.12 and 2.54 units respectively of energy consumed, whereas 3.88, 2.91 and 2.67 units were required when a ration of Jersey origin was used, a result

favoring the latter when the skim- and 2.5 percent milks were fed and the former when rich milk was fed.

The comparisons between Holstein and Jersey skimmilks favor the latter, taking into account both total gain and economy of production. This was to be expected, because the Jersey skimmilk carried more units of energy than did its competitor. Since, however, in this particular section the effect of fat on body development as influenced by the size of the fat globules is the matter under consideration, further discussion of this skimmilk group is unnecessary. When 2.5 percent milk was fed, the Holstein ration produced per 1,000 Calories consumed, a total weight of 112 grams, containing 49 grams dry matter which carried 337 Calories, 68 of which were derived from protein and 269 from fat. The Jersey ration produced 106 grams, 51 of which was dry matter, containing 362 total Calories, 60 derived from protein and 301 from fat. These differences, though slight, indicate a larger fat retention by the group fed Jersey milk.

This outcome was reversed when the 5 percent milks were fed. The Holstein milk produced 107 grams of total gain to the 1,000 Calories consumed, and 56 grams of this gain was dry matter. Its Calorie equivalent was 415, 60 being derived from protein and 355 from fat. The Jersey 5 percent milk per 1,000 Calories consumed produced a total gain of 109 grams, a dry matter gain of 53 grams, and a retention of 394 Calories, 59 as protein and 335 as fat.

These Calorie utilization differences are small and, furthermore, are in opposite directions, thus tending to confirm the conviction that at best the size of the fat globules is but a minor factor in the determination of the adaptability of milk as food for young animals.

The percentage utilization of the available Calories in the food consumed is shown in table XX. The maintenance feature here introduced was explained on page 42.

TABLE XX—PERCENTAGE UTILIZATION OF PHYSIOLOGICALLY AVAILABLE CALORIES IN FOOD

	Holstein skim-milk		Jersey skim-milk		Holstein 2.5% milk		Jersey 2.5% milk		Holstein 5% milk		Jersey 5% milk	
	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain
Total Calories	19	24	18	27	15	34	13	36	13	41	13	33
Protein Calories.....	8	21	7	19	10	27	8	23	12	32	12	31
Milk sugar and fat Calories..	27	26	27	34	17	36	15	41	13	44	14	42
Ash	..	25	..	23	..	29	..	27	..	34	..	25

The total Calorie utilization for purposes of gain seems slightly to favor the Jersey skim- and 2.5 percent milks, whereas when the 5 percent grade was fed the Holstein milk was favored. So far as protein utilization is concerned the Holstein milk always was advantaged the figures being 21, 27 and 32 percents in the case of the Holstein and 19, 23 and 31 percents in the case of the Jersey milk. The milk sugar and fat Calories also were utilized more thoroughly when Jersey skim- and 2.5 percent milks were fed, but the reverse was true when the richer grades were used.

Similar relations to those just enumerated occur when the percentage excess of food over maintenance is calculated. This is shown in table XXI.

TABLE XXI. PERCENTAGE EXCESS FOOD OVER MAINTENANCE UTILIZED FOR GROWTH

	Holstein skimmilk	Jersey skimmilk	Holstein 2.5% milk	Jersey 2.5% milk	Holstein 5% milk	Jersey 5% milk
Total Calories	30	33	40	41	47	45
Protein Calories	23	20	30	25	36	35
Fat Calories	36	47	43	48	51	49

The following tables show the composition of equal weights of the gain made and of the food consumed, stated as Calories.

TABLE XXII—CALORIES IN ONE KILO OF GAIN

	Holstein skimmilk	Jersey skimmilk	Holstein 2.5% milk	Jersey 2.5% milk	Holstein 5% milk	Jersey 5% milk
Protein	713	698	600	573	560	540
Fat	1268	1508	2400	2852	3299	3068
Total	1981	2206	3000	3425	3859	3608
Ash (grams)	42	40	34	33	32	30

TABLE XXIII. CALORIES (AVAILABLE) IN ONE KILO OF FOOD CONSUMED

	Holstein skimmilk	Jersey skimmilk	Holstein 2.5% milk	Jersey 2.5% milk	Holstein 5% milk	Jersey 5% milk
Protein	145	164	145	157	138	157
Milk sugar	198	197	200	194	196	198
Fat	5	4	223	240	391	460
Total	348	365	568	591	725	815
Ash (grams)	6.9	7.3	7.3	7.3	7.1	7.3

The protein Calories in the Jersey milks exceeded those in the Holstein milks; but more protein Calories were retained in the tissues of

the Holstein-milk-fed animals. This may indicate possibly that the nitrogenous compounds of Holstein milk are utilized more readily for body growth than are those of Jersey milk.

Calculating from tables XXII and XXIII the protein, carbohydrate and fat ratios, taking protein as unity, we have the following summary.

TABLE XXIV—RATIOS

	In food consumed				In gain		
	Protein	Milk	sugar	Fat	Protein	Fat	
Holstein skimmilk	1	:	1.4	:	1	:	1.8
Jersey skimmilk	1	:	1.2	:	1	:	2.2
Holstein 2.5 percent milk	1	:	1.4	:	1	:	4.
Jersey 2.5 percent milk...	1	:	1.2	:	1	:	5.
Holstein 5 percent milk...	1	:	1.4	:	1	:	5.9
Jersey 5 percent milk....	1	:	1.3	:	1	:	5.7

The skimmilk rations produced gains closely similar to the average gains displayed by 16 pigs as shown on page 45. On the other hand, the 2.5 percent milks (nutritive ratios Holstein, 1 : 2.9; Jersey, 1 : 2.7) produced a gain much richer in fat than that made by the average of 26 pigs, as shown on the same page. The results secured when 5 percent milks of both types were fed agree well with those previously discussed.

CONCLUSIONS

1. No superiority in grade Holstein skimmilk as compared with that of grade Jersey origin was observed; in fact the balance swings if anything slightly in the other direction.

2. When 2.5 percent milks of grade Jersey and of grade Holstein origins were fed, the animals did uniformly well. They exhibited no marked preference for either milk. The analytical results seemed slightly to favor the Jersey-milk-fed group.

3. When 5 percent milks were fed, the animals did uniformly ill, so far as could be noted by observation. Clinical studies of the two groups indicated no essential differences.

4. The physiological economy of production slightly favored the grade Jersey milk.

5. If on account of the fact that its fat globules are smaller, Holstein milk is superior as a food for the young as compared with the milk containing relatively large fat globules, such a superiority certainly was not clearly manifested in these trials. If it exists, the writers are inclined to believe that it is practically a negligible factor.

6. The superiority for infant feeding attributed to Holstein milk, if really existent, in the opinion of the writers is far more likely to lie in its relatively low fat content than in the relatively small size of its fat globules.

IX. HOMOGENIZED MILKS

HOMOGENIZATION OF MILK FAT

Milk is homogenized when it is rendered homogeneous, when its various particles are reduced as nearly as may be to a uniform size. This condition is brought about by means of a machine which consists essentially of a system of three or more pumps which force the milk through a small aperture against a hard surface, under a pressure of from 1,000 to 5,000 pounds to the square inch. This treatment breaks the fat globule into many smaller globules or particles, and makes of the milk a more nearly complete emulsion, thus greatly retarding the separation of cream (see plate V, opposite page 64). It is claimed that homogenized milk is more easily digested on account of the greatly reduced size of its particles.

The results of the trials thus far discussed seemed to indicate that Holstein milk is no better adapted to infant feeding than is Jersey milk, when the fat contents of the two milks are identical; that in this respect the size of the fat globule is either a negligible or a non-existent factor. Yet there are those who earnestly believe in the dogma of the superiority of Holstein milk for this purpose, basing their belief upon the theory that a portion of the fat is absorbed in the intestinal tract in the same condition in which it is ingested and that the more minute the subdivision of a nutrient the more easily it is absorbed and the greater its nutritive value. If this point of view is valid, homogenization of milk should be worth while economically.¹ Manufacturers of homogenizing machinery very naturally have accepted and disseminated this doctrine.

The first direct testimony touching the value of homogenized milk for infants which has come to the writers' attention is furnished by Eichholz (16), who recommends it for invalids and in cases of forced feeding. This milk, however, was subjected to a high temperature in order to sterilize it in addition to being homogenized. Later, Birk (7) published an unfavorable report.

¹ In this connection see pages 98-100, concerning digestion of fat.

It is stated by some observers that fat is absorbed in the same form in which it is ingested. This view is not inconsistent with that of physiologists who have noted that when certain fats are consumed in considerable quantities, the fat retained as body growth partakes noticeably of the quality of the fat consumed. This observation was confirmed by the results of our own trials whenever corn oil and skim-milk were fed as set forth on the next few pages. These observations tend to support the theory that fat, in part at least, is absorbed before being saponified; yet Hawk (25, p. 130) maintains that fat is not absorbed in the form of an emulsion, i. e. before it is saponified; and Halliburton (22, p. 106) states that fat is absorbed entirely as glycerin and fatty acids and that emulsifying, though possibly advantageous, is not essential to fat digestion.

The photomicrographs of Jersey, Holstein and homogenized Jersey milk fat (plate I, opposite page 32) indicate that the Holstein globule is a little smaller than the Jersey globule and, furthermore, that the homogenization process, particularly at 185° F., decidedly reduced the size of the fat globules. The writers feel that any organism sensitive enough to recognize the slight differences in size between Holstein and Jersey fat globules should distinguish the normal from the homogenized milk fat, between which still greater differences exist.

In order, therefore, to study the efficiency of the homogenization process, and indirectly to subject to a yet more rigid test the question as to the relation of the size of the fat globule to the service of a milk for purposes of infant feeding, a homogenizer was installed in the dairy laboratory and operated daily for about five months during the summer of 1910.

HOMOGENIZATION OF CASEIN

The writers found that the homogenization process modified the casein in a manner interesting to the student of infant feeding problems. It so affected it that the curd formed from homogenized milk did not become hard and tough as is the case with the curd of untreated milks. The milk thus treated coagulated as promptly as did the control samples, but its curd was so tender and flocculent that it took fully five hours completely to precipitate as compared with 20 minutes when normal milk was coagulated. At the end of six hours the homogenized curd was still so tender that it broke when attempts were made to remove it, whereas the curd formed from the control samples was a tough, solid mass. These curds were drained and

gently pressed; yet after 48 hours the homogenized curd was still tender and friable. These divergencies are somewhat unsatisfactorily indicated in plate V, opposite page 64. In this connection it is interesting to note that it has been stated in private communication to one of the writers from one of the Wisconsin station staff that commercial cheeses of the American, brick, and Limburger varieties made at that institution from homogenized milk uniformly have possessed a short grain and were tender and friable.

These observations lead one to query whether it is not the subdivision of the casein rather than that of the fat which is effective if as a matter of fact homogenization improves milk for infant feeding. This point has not yet been determined experimentally, unless it be in relation to buttermilk feeding.

NORMAL MILK VS. HOMOGENIZED MILK

In order to obviate the introduction of more than one varying factor, the fat used during a portion of these trials was subjected to homogenization at a low temperature, 85° F. being employed lest coagulation due to high temperature might ensue. Furthermore, the fat was treated thus in the form of a 25 percent cream in order that, so far as possible, this nutrient only should be subjected to the homogenization process. The cream then was reduced to the fat grade desired by the addition of centrifugally separated skim milk. Thus as far as possible the size of the fat globule was made the single variant in these trials. The tests conducted in Germany with homogenized milk were made with a product in which not only the fat but also the casein had been homogenized, a product furthermore in which such chemical and other changes as may be induced by high temperatures had been wrought.

If the homogenization of the fat globules in milk is advantageous, in nutrition, the fact should be manifested in one or more of four ways:

- (1) In producing a greater gain per unit of the food consumed.
- (2) In a more complete utilization of the fat.
- (3) In the increased ability of the animal to ingest milk containing a higher percentage amount of fat.
- (4) In its increased ability to ingest a larger quantity of medium fat milk.

These manifestations should appear in greater palatability of the food, increased rate of gain, in the general well being of the animal

and in the effect upon the number of units of food material required for the deposition of a unit of body tissue or, expressed in other words, in the percentage utilization of the energy consumed.

Inasmuch as the manufacturers of homogenizers have suggested that their machines may be made the instruments whereby cheap vegetable and animal fats may be utilized for commercial pork production, it was thought advisable to test the question at this time. Consequently a commercially pure corn oil was homogenized with skim milk and fed to certain animals.

The general plan of the trials where the homogenization process was carried on at 185° F. differed somewhat from that just outlined. All of the animals were fed skim milk at the start and, later, a milk carrying one percent of fat of the kind under test, e. g. normal, homogenized, etc. The fat contents of these milks gradually were increased until 3 percent milk was being consumed. When all were working smoothly, the quantity of milk fed was held constant and the percentage of fat was increased, in order to observe which lot surfeited first. In every case the pigs receiving homogenized corn oil were the first to revolt, followed by those fed homogenized milk fat. The normal milk-fed animals endured a higher fat percentage than those fed either of the other rations, yet while on high fat all of them did poorly. The fat percentages in their rations then were decreased to a 3 percent basis and these reduced rations were fed until all the animals were once more in good condition, when the fat contents again were increased, the quantity of food fed being held constant in all cases; and the same outcome again was secured.

Twelve pigs from two litters were fed in these trials, two from each litter being placed on each of the three rations. It should be observed that although four pigs were entered in each class, one on the homogenized and one on the corn oil rations did so poorly as clearly to indicate their constitutional inability to compete with their mates. Hence their records are eliminated. Had they been included, the outcome would have been slightly less favorable to the homogenization process.

All of the pigs which received normal milk fat consumed their portions greedily and made prompt gains, while those receiving homogenized milk fat apparently disliked it at first. It was observed throughout the entire trial that the pigs from all the litters which were fed homogenized fat were not inclined to gorge themselves, that it was not relished as well as was the fat derived from the normal milk

even though the animals to which it was fed had never been accustomed to cows' milk. Those animals which were fed the corn oil-milk did not easily adapt themselves to this diet and made no attempt to consume it in excess. Corn oil in the kernel is relished by all stock, but the refined product seems less palatable.

Microscopic examination of the fat homogenized at 85°F. indicated that the treatment was not particularly effective, whereas homogenization of the fat globule conducted at 185°F. was far more thorough, as shown in photomicrographs in plate I, opposite page 32.

EFFECT OF FOOD ON COMPOSITION OF BODY GAIN

Table XXV shows the effect on the composition of the body gain when homogenized milk and corn oil fats are compared with untreated milk. This table is divided into two sections, the upper showing the results when homogenization was conducted at 85°F, and the lower when 185°F. were employed. The necessary modifications in the general plan of feeding which have just been explained should be remembered when considering the lower portion of the table. It will be observed at the outset that fewer animals were employed in these trials than in those which dealt with the effect of feeding skim-, 2.5 percent and 5 percent milks. Eighteen animals distributed into groups of five, five and eight, were fed the several rations when homogenization at 85° F. was practised, while 10 animals distributed into groups four, three and three, were used when a temperature 185° F. was used. The former trials were conducted for 52 days, the latter for 67 days.

TABLE XXV—EFFECT OF FOOD ON COMPOSITION OF BODY GAIN

	Weight	Water	Dry matter	Ash	Protein	Fat	Milk sugar	Nutritive ratio of food	Ratio, protein to fat in gain	Average daily gain	Average daily dry matter gain
	Kilos	%	%	%	%	%	%	1:	1: grams	grams	grams
HOMOGENIZED AT 85° F.											
ONE PIG FED NORMAL MILK, TWO HOMOGENIZED MILK AND TWO HOMOGENIZED CORN OIL AND SKIMMILK, APPROXIMATELY 2.5 PERCENT FAT											
Food, Norm.	283.0	87.78	12.22	0.75	3.78	2.96	4.73	3.02	...	...	...
Food, Homo.	301.5	88.41	11.59	0.75	3.70	2.36	4.78	2.72	...	...	...
Food, C. oil	328.9	88.20	11.80	0.75	3.65	2.61	4.74	2.92	...	...	...
Gain, Norm.	22.07	58.77	41.23	3.91	15.03	22.00	...	...	1.46	424	175
Gain, Homo.	23.18	55.00	45.00	3.19	15.26	26.51	...	...	1.74	446	201
Gain, C. oil	26.50	55.68	44.32	3.54	15.91	24.42	...	...	1.54	510	226
HOMOGENIZED AT 85° F.											
ONE PIG FED NORMAL MILK, TWO HOMOGENIZED MILK AND TWO HOMOGENIZED CORN OIL AND SKIMMILK; 4.5 TO 5.5 PERCENT FAT											
Food, Norm.	255.6	85.45	14.55	0.73	3.65	5.57	4.61	4.69	...	...	...
Food, Homo.	318.5	86.56	13.44	0.74	3.64	4.35	4.71	3.99	...	...	...
Food, C. oil	319.2	86.45	13.55	0.75	3.65	4.46	4.72	4.05	...	...	...
Gain, Norm.	25.88	57.69	42.31	3.01	14.98	23.98	...	...	1.60	498	211
Gain, Homo.	29.36	57.44	42.56	3.37	16.03	23.05	...	...	1.44	565	240
Gain, C. oil	28.64	54.38	45.62	3.24	14.00	27.45	...	...	1.96	551	251
HOMOGENIZED AT 85° F.											
TWO PIGS FED NORMAL MILK, THREE HOMOGENIZED MILK AND THREE HOMOGENIZED CORN OIL AND SKIMMILK; 6.7 TO 8.2 PERCENT FAT											
Food, Norm.	268.9	83.06	16.94	0.72	3.44	8.21	4.57	6.71	...	...	...
Food, Homo.	301.0	84.54	15.46	0.72	3.47	6.67	4.60	5.66	...	...	...
Food, C. oil	274.4	84.43	15.57	0.70	3.51	7.10	4.26	5.76	...	...	...
Gain, Norm.	26.29	46.52	53.48	2.62	11.40	39.52	...	...	3.47	506	270
Gain, Homo.	30.53	47.42	52.58	2.63	11.71	37.34	...	...	3.19	587	309
Gain, C. oil	26.13	52.66	47.34	2.80	13.89	29.73	...	...	2.14	503	238
HOMOGENIZED AT 185° F.											
FOUR PIGS FED NORMAL MILK, THREE FED HOMOGENIZED MILK AND THREE FED HOMOGENIZED CORN OIL AND SKIMMILK; 4.7 TO 7 PERCENT FAT											
Food, Norm.	159.9	83.99	16.01	0.71	3.60	7.06	4.64	5.71	...	...	...
Food, Homo.	156.7	86.19	13.81	0.71	3.61	4.71	4.78	4.25	...	...	...
Food, C. oil	152.8	86.54	13.46	0.71	3.56	4.78	4.41	4.26	...	...	...
Gain, Norm.	14.57	66.43	33.57	2.79	13.12	16.92	...	...	1.29	217	73
Gain, Homo.	13.48	69.97	30.03	2.86	14.26	12.06	...	...	0.85	201	60
Gain, C. oil	13.21	71.74	28.26	2.79	13.48	10.79	...	...	0.80	197	56

Deferring for the present the consideration of the results secured with the corn oil, for the reason that they have no direct bearing on infant feeding, and turning at once to the study of the results attained when the normal and the homogenized milks were fed, it appears that the true composition of the gain made by the 2.5 percent fat groups may be measured, along the lines mentioned in previous

discussions, by the protein to fat ratios which vary from 1:1.46 to 1:1.74, being less with the normal fat-fed animals than with their competitors. This would indicate an increased retention of fat in the body gain when homogenized fat was fed. The result stands out the more strongly in contrast with the protein to fat ratio observed when 27 pigs were fed on medium milk, 1:1.61 (page 32), and because the analyses showed that as a matter of fact the normal milk carried almost 3 percent fat and the homogenized only 2.3 percent.

When, however, homogenized fat in milk of about 5 percent grade was fed, the results were reversed. A larger proportion of fat, associated with protein, was stored when the normal milk was fed—normal 1:1.60, homogenized 1:1.44. This was due to the relatively high protein percentage in the tissue of the homogenized milk-fed animals rather than to a decrease in the amount of fat stored in the gain. In no case was the retention as large as was indicated for this grade of food by earlier work based on the average of 15 animals. It seems probable that divergencies in milk standardization may have had a bearing on the somewhat increased ratio of protein to fat observed when normal milk was fed.

When homogenized and normal milks of high fat contents—6.67 to 8.21 percents—were fed, relatively less protein and more fat were stored, the protein to fat ratios being 1:3.47 and 1:3.19. These ratios considerably exceed those obtained when approximately 5 percent milk was fed, as well as those obtained in the earlier trials with 5 percent milk.

It should be noted that the standardization divergencies heretofore mentioned, do not obscure or alter the fact that an excessive fat content in the ration is reflected in the gains.

In the lower portion of the table setting forth the results secured when the homogenization process was conducted at 185° F., the column headed, "Gain per day," shows that daily gains of 217, 201 and 197 grams and dry matter daily gains of 73, 60 and 56 grams were secured. Comparison of these data with similar figures dealing with the last group discussed, and with the direct weights, show that these results were unsatisfactory. Indeed, none of the 10 animals responded to their rations as well as might be desired. The column headed, "Ratio protein to fat in gain," shows ratios of 1:1.29 and of 1:0.85. These were far below normal in every case, in view of the quality of the ration eaten. The animals thus fed showed poor tolerance for fat. The fat retentions, as evidenced by the percentages of fat in the

gain and also in the dry matter, were related rightly to the fat in the food consumed, but they were far below the results attained with the animals fed with milk homogenized at 85° F. instead of at a temperature 100° higher.

The conduct of the test of homogenization at 185° F. differed from that of the other runs (see page 58). The high fat percentage in the normal milk ration was not due to faulty standardization, but to the fact that this particular lot of pigs clearly indicated by their daily clinical record their ability to consume a ration with a higher fat content than that of the rations fed to their companions. That they utilized but poorly what they consumed, when measured as body gain, is another matter.

Table XXVI, showing the weekly percentage gains, likewise exhibits the results of homogenization at 85° F. and at 185° F. When the lower temperature was employed, the gross live weight was doubled first by the normal-fed, next by homogenized milk fat-fed, and lastly by the homogenized corn oil-fed animals, when 2.5 percent and when 5 percent milks were fed; but when the 8 percent milk was used, the group fed homogenized milk outstripped that fed normal milk, while the homogenized corn oil group was outclassed. When the higher temperatures were used, the pigs were a week longer in doubling their weights, but in this instance the homogenized milk at that particular point led the normal and homogenized corn oil milks.

TABLE XXVI—AVERAGE GAIN PER WEEK

HOMOGENIZATION AT 85° F.											
	Number average	Initial in weight kilos	7 days	14 days	21 days	28 days	35 days	42 days	49 days	56 days	63 days
Normal 2.5 %.....	1	9.08	45	70	105	125	165	205	243		
Homogenized 2.5 %...	2	10.44	30	49	79	104	137	165	222		
Homog. corn oil 2.5 %.	2	13.62	25	46	74	93	118	148	195		
Normal 5 %	1	9.08	36	79	117	140	180	225	285		
Homogenized 5 %.....	2	11.58	32	64	95	125	163	202	254		
Homog. corn oil 5 %..	2	13.16	26	56	81	102	136	171	218		
Normal 8 %	2	12.03	27	55	87	109	149	177	219		
Homogenized 8 %	3	12.56	29	55	88	117	155	193	243		
Homog. corn oil 8 %..	3	14.83	19	47	72	90	117	148	176		

HOMOGENIZATION AT 185° F.											
	Number average	Initial in weight kilos	7 days	14 days	21 days	28 days	35 days	42 days	49 days	56 days	63 days
Normal	4	5.61	12	30	56	86	91	113	152	193	260
Homogenized ...	3	5.14	10	23	48	81	101	122	164	200	263
Homogenized corn oil	3	5.14	19	40	54	72	94	135	163	191	257

Table XXVII, which has to do with the "growth of young pigs," concisely summarizes the situation. The available Calories which were fed to the animals are shown in line 5, following which are displayed relations based on comparisons between the gain produced and the total food, the dry matter in food, and the Calories fed. The gross gains and dry matter gains per 1,000 Calories consumed (lines 8 and 9) are expressed as grams and they are expressed also as total Calories as well as protein and fat Calories (line 10). Thus, for example, from 1,000 Calories consumed there were retained in the case of the pigs fed the normal 2.5 percent milk, 132 grams gross gain and 54 grams dry matter gain, containing 348 Calories, 81 of which were derived from protein and 267 from fat. These data may be enumerated similarly for the other rations.

These results clearly indicate, as already has been shown in previous tables, that the number of Calories in the food and their sources, whether from protein, milk sugar, or fat, are essential factors in the production of normal body tissue.

The pigs used in the high temperature homogenization trials were younger and smaller at the start than those used in the previous homogenization runs. They consumed less total food Calories, though fed for 15 days longer.

The starch equivalents appear in line 11. Disregarding the corn oil-fed groups for reasons which are elsewhere indicated, a study of food efficiencies indicates that when the milks homogenized at 85°F. are considered, more normal milk was required to produce a unit of gain than of the homogenized; and this holds true whether 2.5, 5 or 8 percent milks were fed. Somewhat more food units were needed to make a pound of gain when the milk homogenized at 185°F. was fed than when the normal milk was fed. This doubtless was due to the increased amount of fat furnished to the normal milk group, for reasons elsewhere explained. The large amount of dry matter needed to produce a unit of dry matter in the gain clearly shows that the animals of this group utilized their food to poor advantage.

TABLE XXVII—GROWTH OF YOUNG PIGS

	Normal 2.5 percent	Homogenized at 85° F.					At 135° F.				
		Homogenized 2.5 percent	Homogenized 5 percent	Normal 5 percent	Homogenized 5 percent	Homogenized 8 percent	Normal 8 percent	Homogenized 8 percent	Normal	Homogenized	Homogenized corn oil
1 Initial weight, kilos	9.08	10.44	13.62	9.08	11.58	13.16	12.03	12.56	5.61	5.14	5.14
2 Final weight, kilos	31.15	33.62	40.12	34.96	40.94	41.80	38.32	43.09	20.18	18.62	18.35
3 Gain, kilos	22.07	23.18	26.50	25.88	29.36	28.64	26.29	30.53	14.57	13.48	13.21
4 Percentage gained	243	222	195	285	254	218	219	243	260	262	257
5 Available Calories fed	167600	161900	183500	206700	225100	226900	277500	270400	150400	115800	111400
6 Total gain per kilo of food consumed (grams)	78	77	81	101	92	90	98	102	95	91	86
7 Dry matter gained per kilo dry matter consumed (grams)	263	299	303	294	292	302	309	345	191	187	182
8 Gain per 1,000 Calories consumed (grams)	132	143	144	125	130	126	95	113	97	116	119
9 Gain in dry matter per 1,000 Calories consumed (grams)	54	64	64	53	56	58	51	59	33	35	34
10 Calories retained as : Total	348	440	420	354	363	392	390	443	203	198	184
growth per 1,000 : as protein	81	90	94	77	86	72	44	54	52	68	66
Calories fed : as fat	267	350	326	277	277	320	346	389	151	130	118
11 Starch equivalent or Calorie ratio, 1: ..	3.02	2.39	2.51	2.97	2.90	2.69	2.70	2.38	5.18	5.33	5.73
12 Ratio, protein to fat in gain, 1:	1.46	1.74	1.54	1.60	1.44	1.96	3.47	3.19	1.29	0.85	0.80
13 Nutritive ratio of food, 1:	3.02	2.72	2.92	4.69	3.99	4.05	6.71	5.66	5.71	4.25	4.26

PERCENTAGE UTILIZATION OF PHYSIOLOGICALLY AVAILABLE CALORIES IN FOOD

Continuing the study of these results, and viewing them from the standpoint of energy supplied and retained as growth, it is noted again that a greater percentage amount is utilized from the homogenized food. When a temperature of 85°F. was employed, a satisfactory utilization of food Calories was secured in all cases, as may be seen by the comparison of 44, 36 and 44 percents (homogenized) and 35, 35 and 39 percents (normal). The protein storage data practically were identical with all grades. As might have been expected, large variations occurred in the milk sugar and fat data, 48, 35 and 46 percents (homogenized) 36, 34 and 40 percents (normal). No stress is laid on the corn oil data.

TABLE XXVIII—PERCENTAGE UTILIZATION OF PHYSIOLOGICALLY AVAILABLE CALORIES
IN FOOD

(Homogenization at 85° F. save in last two cases in table, when 185° F. was used)

	Normal 2.5%		Homo- genized 2.5%		Homo- genized corn oil 2.5%		Normal 5%		Homo- genized 5%		Homogenized corn oil 5%	
	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain
Total	16	35	18	44	19	42	14	35	15	36	16	39
Protein	11	33	11	33	13	37	13	44	13	43	14	37
Milk sugar												
and fat....	17	36	20	48	21	44	14	34	16	35	16	40
Ash	..	41	..	33	..	38	..	42	..	42	..	39

	Normal 8 %		Homo- genized 8 %		Homo- genized corn oil 8 %			Normal		Homo- genized		Homo- genized corn oil	
	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain		Maintenance	Gain	Maintenance	Gain	Maintenance	Gain
Total	12	39	13	44	14	34	14	20	17	20	18	18	18
Protein	15	34	15	36	16	40	16	35	15	36	16	34	34
Milk sugar													
and fat....	11	40	13	46	14	33	14	18	18	16	18	15	15
Ash	..	36	..	37	..	38	..	36	..	34	..	34	34

It has been shown that the normal milk-fed animals consumed higher percentages of fat, and in many cases larger amounts of fat, than did the groups fed homogenized milks. On this account and in view of the data secured with earlier runs, the writers feel that the increased percentage retention of milk sugar and fat favoring homogenization, indicated in the table under discussion, justified their conclusions as stated on pages 68-69.

The percentage of ash retained in the gain is shown only as a matter of interest. It is assumed that it is derived solely from the ash of the food, yet since these animals had access daily to moist subsoil their mineral content possibly may have been thus affected. The results indicate that the food furnished plenty of ash.

Being young and of light weight, the 185°F. homogenization groups (right hand columns) utilized their food less thoroughly than did their mates. Retention data for the three lots were closely alike, but slight differences appearing at any point. In view of the results secured in the earlier studies on the retention of fat in body gain compared with the fat in the food, and remembering that the animals in this group which were fed normal milk received considerably more fat than did their competitors, the writers believe that the practical agreement of utilization percentages as between the pigs fed the normal and the homogenized milks should be interpreted as favoring the latter.

In table XXIX is shown the percentage excess of food over maintenance utilized for growth. This table further demonstrates that when an arbitrary maintenance requirement is introduced (page 42), the conclusions heretofore set forth as to the effect of homogenization seem warranted.

TABLE XXIX—PERCENTAGE EXCESS FOOD OVER MAINTENANCE UTILIZED FOR GROWTH

	Normal 2.5 percent	Homogenized 2.5 percent	Homogenized corn oil 2.5 percent	Normal 5 percent	Homogenized 5 percent	Homogenized corn oil 2.5 percent	Normal 8 percent	Homogenized 8 percent	Homogenized corn oil 2.5 percent	Normal	Homogenized	Homogenized corn oil
	2.5 percent	2.5 percent	2.5 percent	5 percent	5 percent	2.5 percent	8 percent	8 percent	2.5 percent	at 85° F.	at 185° F.	at 185° F.
Total Calories.....	42	54	52	41	43	46	44	51	40	23	24	22
Protein Calories	37	37	43	51	49	43	40	42	48	42	42	40
Fat Calories	43	60	56	40	42	48	45	53	38	21	20	18

Increased fat utilization, which has been interpreted just now in favor of the homogenization process, is not necessarily an essential argument in favor of the indiscriminate feeding of homogenized milk. With the knowledge in hand as a result of these five months of trials, the writers now could plan feeding trials involving the use of this process which, in their judgment, would be more likely clearly to develop the desired points, paying attention particularly to closer standardization and to the feeding of uniform amounts of milk solids, regardless of the apparent desire of the animals to consume more food of the normal milk type. The clinical data, however, are valuable in the interpretation of results.

The following summary tables show the Calories of protein, milk sugar and fat in each kilo of the several foods consumed together with the protein and fat Calories in the deposited tissue.

TABLE XXX—CALORIES IN ONE KILO OF GAIN

	Homogenized at 85° F.										at 185° F.	
	Normal 2.5 percent	Homogenized 2.5 percent	Homogenized corn oil 2.5 percent	Normal 5 percent	Homogenized 5 percent	Homogenized corn oil 5 percent	Normal 8 percent	Homogenized 8 percent	Homogenized corn oil 8 percent	Normal	Homogenized	Homogenized corn oil
Protein	616	626	653	614	657	574	467	480	570	538	585	553
Fat	2028	2446	2253	2212	2127	2531	3646	3446	2743	1559	1113	996
Total	2644	3072	2906	2826	2784	3105	4113	3926	3313	2097	1698	1549
Ash (grams) ..	39	32	35	30	34	32	26	26	28	28	28.6	28

TABLE XXXI—CALORIES AVAILABLE IN ONE KILO OF FOOD CONSUMED

	Homogenized at 85° F.												at 185° F.		
	Normal 2.5 percent	Homogenized 2.5 percent	Homogenized corn oil 2.5 percent	Normal 5 percent	Homogenized 5 percent	Homogenized corn oil 5 percent	Normal 8 percent	Homogenized 8 percent	Homogenized corn oil 8 percent	Normal	Homogenized	Homogenized corn oil			
Protein	147	144	142	142	142	141	134	135	137	140	141	139			
Milk sugar....	185	186	187	180	183	179	178	179	166	181	186	172			
Fat	260	206	229	487	382	391	720	585	622	620	412	419			
Total	592	536	558	809	707	711	1032	899	925	941	739	730			
Ash (grams) ..	7.5	7.5	7.5	7.3	7.4	7.5	7.2	7.2	7.0	7.1	7.1	7.1			

Comparisons between the two are interesting, particularly those between the 2.5 and the 8 percent fat rations, which illustrate again

the large deposition of fat in the body gain when excessively rich milks are fed to young animals.

Calculating these figures on a unit or nutritive ratio basis, we have the following statement:

TABLE XXXII—RATIOS

	In food consumed			In gain		
	Protein	Milk	sugar	Fat	Protein	Fat
Normal 2.5 percent milk.....	1	:	1.3	:	1.8	1 : 3.3
Homogenized 2.5 percent 85° F..	1	:	1.3	:	1.4	1 : 3.9
Homogenized corn oil 85° F....	1	:	1.3	:	1.6	1 : 3.5
Normal 5 percent milk.....	1	:	1.3	:	3.4	1 : 3.6
Homogenized 5 percent 85°F..	1	:	1.3	:	2.7	1 : 3.2
Homogenized corn oil 85° F....	1	:	1.3	:	2.8	1 : 4.4
Normal 8 percent milk.....	1	:	1.3	:	5.4	1 : 7.8
Homogenized 8 percent 85° F..	1	:	1.3	:	4.3	1 : 7.2
Homogenized corn oil 85° F. .	1	:	1.2	:	4.5	1 : 4.8
Normal	1	:	1.3	:	4.4	1 : 2.9
Homogenized 185° F.....	1	:	1.3	:	2.9	1 : 1.9
Homogenized corn oil 185° F...	1	:	1.2	:	3.0	1 : 1.8

Such differences as occur in the ratio of the constituents in the food are found mainly in the fat column; hence those occurring in the body gain must be due chiefly to the fat consumed. Thus, comparing normal 2.5 percent with normal 8 percent milk, it appears that the explanation of the ratios 1: 1.8 and 1: 5.4 in the fat column are to be found in the protein to fat variation in the added body tissue of 1: 3.3 and 1: 7.8 respectively. The 1: 7.8 ratio indicates excessive fat deposition, and the general vitality of the animals betrayed this condition. Similar comparisons may be made between other members of these groups. The low tolerance of large amounts of homogenized corn oil is shown by the ratio of protein to fat of 1: 4.8.

The relatively poor utilization of food by the group fed milk homogenized at 185° F., again is clearly brought out.

CONCLUSIONS

1. The homogenization of the fat does not seem to be helpful in the feeding of the young, if we may judge by the clinical evidences. The pigs fed the milks thus treated ate their food less greedily and, whenever the fat content of their ration was increased, went "off feed"

more quickly than did those receiving milk containing normal fat. However, the curds formed from milk the casein of which had been homogenized, were made so much more flocculent and friable as a result of this process that the writers are led to feel that perhaps benefit may be expected from such treatment.

2. The quantity of fat fed is of much more importance in the constitution of the body tissue than is the size of the fat globules.

3. The effects of homogenization are more noticeable when medium amounts of fat—2 to 3 percent—are fed than when larger quantities are furnished. Under these conditions there appears to be a slightly increased fat utilization favoring homogenization.

X. EVAPORATED AND SWEETENED CONDENSED MILKS

These tests were conducted with the purpose of determining the food values of evaporated and sweetened condensed milks when employed as food for the young. Three litters of pigs were used, Nos. 147 to 153, 154 to 160, and 161 to 167. Two pigs from each litter were placed on each class of milk in order to lessen the effect of individuality. Subsoil earth was eaten freely by each pig. The subdivision of each class for the purposes of testing the effect of inorganic calcium phosphate is explained later.

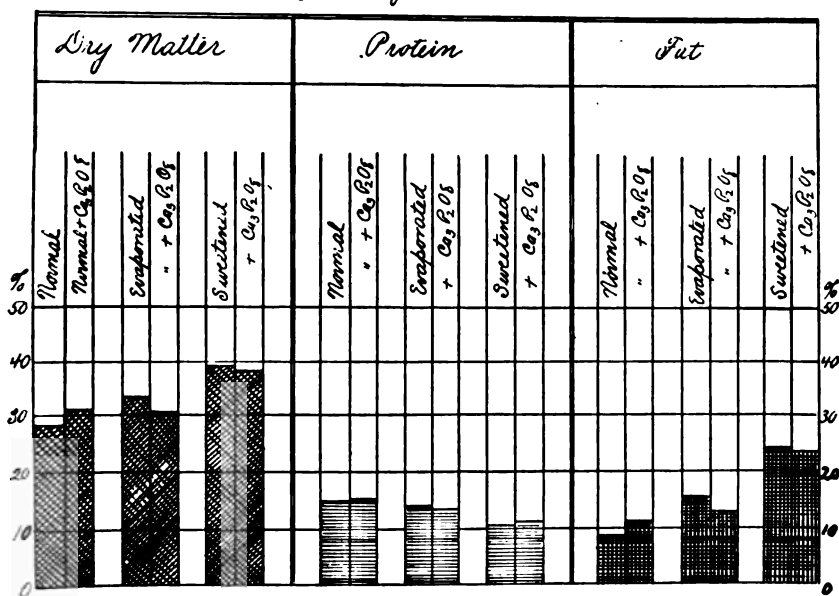
This was a very satisfactory trial. The food consumption was quite uniform and the compositions of the normal and evaporated milks were essentially alike. Of course the total solid and (cane) sugar contents of the sweetened condensed milk were increased whereas its protein and fat contents were decreased as compared with those in the milks with which it was in competition. The nutritive ratios of the three milks were 1:3.52, 1:3.96 and 1:8.65, the latter being high on account of its cane sugar content. The ratios of protein to fat in the three milks were much the same, but the contents of protein and ash in the sweetened condensed milk were relatively deficient. The normal milk contained 0.7 percent ash and 3.5 percent protein whereas the sweetened product carried only 0.3 percent ash and 1.6 percent protein. These deficiencies, as well as the shortage in fat, are due to the use of large amounts of cane sugar by the manufacturers in the interests of the preservation of the product. They are betrayed in the 9.8 percent milk- and cane sugar contents of the sweetened products, nearly double those of the other two milks.

TABLE XXXIII—EFFECT OF FOOD ON COMPOSITION OF BODY GAIN.

	Weight	Water	Dry matter	Ash	Protein	Fat	Milk sugar	Nutritive ratio of food	Ratio, protein to fat in gain	Average daily gain	Average daily dry matter gain
	Kilos	%	%	%	%	%	%	1:	1: grams	grams	grams
THREE PIGS FED NORMAL MILK AND THREE FED SAME PLUS CALCIUM PHOSPHATE 49 DAYS											
Food	107.0	87.28	12.72	0.70	3.57	3.29	5.16	3.52	...	...	...
Gain, norm...	12.32	71.52	28.48	3.01	15.66	8.55	...	...	0.55	251	72
Gain, norm. +	10.38	68.38	31.62	3.86	15.57	11.29	...	...	0.73	212	67
THREE PIGS FED EVAPORATED MILK AND THREE FED SAME PLUS CALCIUM PHOSPHATE, 49 DAYS											
Food	107.0	87.47	12.53	0.67	3.29	3.55	5.02	3.96	...	...	...
Gain, evap. ..	12.35	66.41	33.59	2.96	14.46	16.07	...	...	1.11	252	85
Gain, evap. +	12.16	69.44	30.56	3.55	13.46	12.81	...	...	0.95	248	76
THREE PIGS FED SWEETENED CONDENSED MILK AND THREE FED SAME PLUS CALCIUM PHOSPHATE, 49 DAYS											
Food	107.0	86.74	13.26	0.30	1.55	1.62	9.79	8.65	...	...	...
Gain, sw. cond.	8.31	60.82	39.18	2.62	10.80	24.41	...	...	2.26	170	66
Gain, sw. cond. +	7.89	61.62	38.38	3.38	11.04	22.71	...	...	2.06	161	62

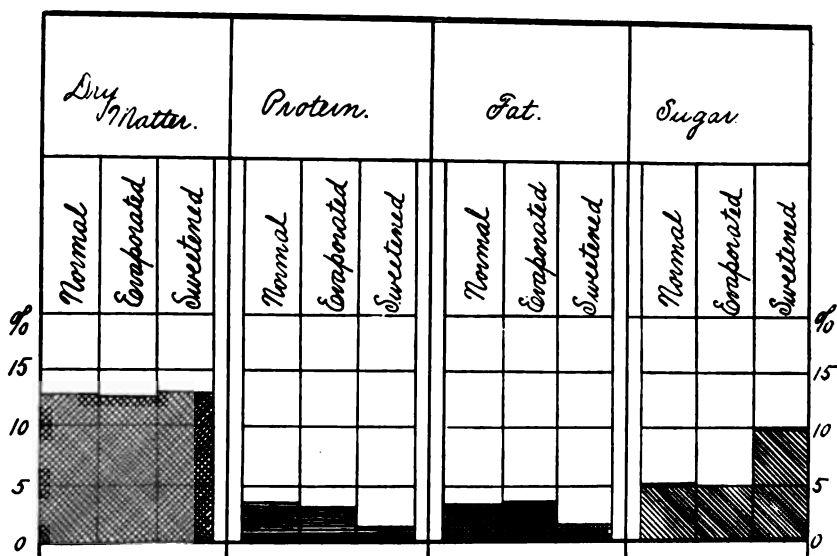
The pigs were fed for 49 days. Those fed the normal, evaporated and sweetened condensed milks without the addition of calcium phosphate gained daily on the average 251, 252 and 170 grams in gross weight, and 72, 85 and 66 grams in dry matter. The addition of calcium phosphate to similar rations fed to other members of the groups apparently caused, or at least in every case was accompanied by, a decrease both in the gross weight and the dry matter gained daily, the results being 212, 248 and 161 grams gross weight and 67, 76 and 62 grams dry matter. The decrease in protein percentage in the body gain when sweetened condensed milk was fed is notable, as well as the increase in fat and the resulting wide ratio between the protein and fat, which greatly exceeds that observed when normal and evaporated milks were fed. The increased percentage of ash in the gain made by all the calcium phosphate groups also is a striking feature.

Graph 6, "Composition of body gain," shows that those animals which consumed the sweetened milk made the most dry matter gain, which, however, carried a low protein and a large fat content. A lessened dry matter content with increased protein and reduced fat percentages, a more desirable combination for growing animals, followed the use of normal and evaporated milks.

Comparison of Body Gain.

GRAPH 6

Graph 7 shows the composition of the rations which were fed. The total dry matter consumption in each ration was essentially identical. The protein, fat and milk sugar contents of the normal and evaporated milks were closely alike, as they were meant to be, but the

Composition of Food Consumed

GRAPH 7

fat and protein contents dropped and that of the sugar was raised in the sweetened product.

These graphs illustrate the fact that a fat but weak infant may be expected when sweetened condensed milk is consumed for any material length of time. Surely it is more than a coincidence that the bodies of these animals which received the sweetened condensed milk contain the largest amount of fat, while those receiving the rations containing the higher protein content stored in their bodies correspondingly larger amounts of muscular tissue.

Photographs of longitudinal sections of representative animals fed these three milks appear in Plate VII, opposite page 64. A study of these pictures will show that those animals which ate normal milk of medium fat grade were superior physically to those fed sweetened condensed milk, but that they were not materially superior to those which consumed evaporated milk. Those which received sweetened condensed milk containing little protein and much sugar, manifestly were inferior in physique to their competitors, an observation confirmed by chemical analysis.

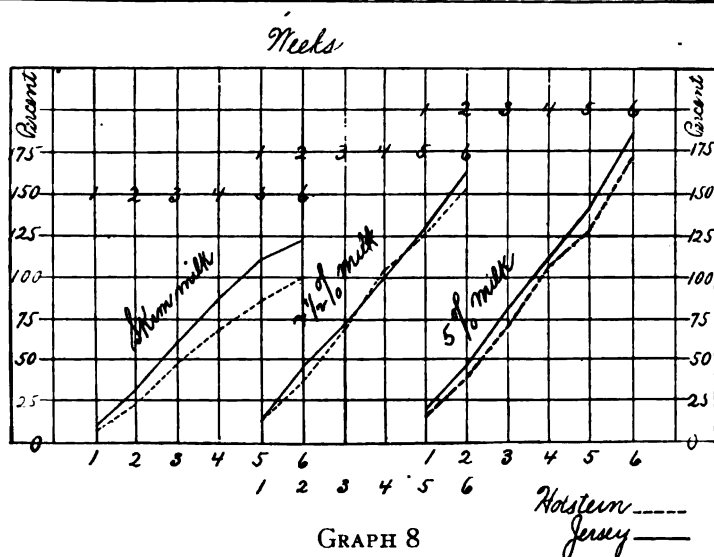
The average weekly gains made by these groups are shown in table XXXIV. The three pigs consuming normal milk of medium fat percentage without calcium phosphate gained the most rapidly. Their mates receiving the calcium phosphate made gains quite similar for about three weeks, but gradually fell behind as the feeding period advanced. This condition was exactly reversed when evaporated milk was fed. The animals fed sweetened condensed milk required more than a week longer feeding in order to double their weight than did the pigs in either of the other groups.

TABLE XXXIV—PERCENTAGE GAINS
(Three animals used in each case)

		Initial weight kilos	Percentage 7 days	14 days	gained 21 days	at 28 days	the 35 days	end 42 days	of 49 days
Normal	Plain	6.22	9	30	57	80	111	143	191
	Calc. phos.	6.51	9	29	50	72	97	135	166
Evaporated	Plain	7.37	9	26	46	68	93	124	167
	Calc. phos.	6.97	7	25	45	71	98	129	175
Sweetened condensed	Plain	6.52	2	16	35	47	67	95	127
	Calc. phos.	6.49	4	15	29	41	61	86	122

A study of the weight lines represented in graph 8 clearly shows that the six pigs consuming normal milk gained more rapidly than those in either of the other two groups, and that the sweetened condensed lot made perceptibly the least and slowest gains. A statement of the average gain made by the pigs fed a standard ration is included with this group for purposes of comparison.

Average Gain per Week Holstein & Jersey Milk



GROWTH OF YOUNG PIGS

In studying the growth of young pigs, table XXXV, it should be recalled that the records made by three healthy individuals appear in the averages shown in each of the six columns. Their average initial weights were quite uniform, the maximum variation being only 1.15 kilos; but at the close of the feeding period weight differences of over 5 kilos existed. The percentage gains varied from 122 to 191, being highest with the normal milk and lowest with the sweetened condensed milk group. The Calories fed practically were the same for the first two groups, while a less amount was consumed by the animals fed sweetened condensed milk.

Considering further only the records of those pigs which ate a milk ration to which no calcium phosphate was added, it will be observed that the animals in the normal group averaged a gain of 259 grams dry matter per kilo of dry matter consumed. They stored as gain for every thousand Calories fed 184 grams, which contained 52 grams of dry matter, and in this gain there were 263 Calories, 118 of which were stored in the form of protein and 145 stored as fat. On the other hand, the sweetened condensed milk group gained only 229 grams per kilo dry matter consumed, and showed a total gain of 133 grams, containing 52 grams of dry matter, equivalent to 359

TABLE XXV—GROWTH OF YOUNG PIGS

	Normal milk		Evaporated milk		Sweetened condensed milk		Standard
	Plain	Calcium phosphate	Plain	Calcium phosphate	Plain	Calcium Phosphate	
1 Initial weight kilos	6.22	6.51	7.37	6.97	6.52	6.49	8.26
2 Final weight, kilos	18.54	16.89	19.72	19.13	14.83	14.38	26.79
3 Gain, kilos	12.32	10.38	12.35	12.16	8.31	7.89	18.53
4 Percentage gained	198	159	168	174	127	122	224
5 Available Calories fed	67090	67270	68000	68000	62400	62350	115900
6 Total gain per kilo of food consumed (grams)	115	97	115	114	78	74	124
7 Dry matter gained per kilo dry matter consumed (grams)	259	241	309	277	229	214	224
8 Gain per 1,000 Calories consumed (grams)	184	154	182	179	133	127	160
9 Gain in dry matter per 1,000 Calories consumed (grams)	52	49	61	55	52	49	55
10 Calories retained as : Total	263	259	377	310	359	322	357
growth per 1,000 : Protein	118	99	108	99	59	57	77
Calories fed : Fat	145	160	269	211	300	265	280
11 Starch equivalent or Calorie ratio 1: ...	4.01	4.06	2.79	3.40	2.93	3.27	2.95
12 Ratio protein to fat in gain 1:	0.55	0.73	1.11	0.95	2.26	2.06	1.62
13 Nutritive ratio of food 1:	3.52	3.52	3.96	3.96	8.65	8.65	3.11

Calories of energy, only 59 of which were in the form of protein, while 300 were in the form of fat. It will be noticed that the gain in dry matter per thousand Calories consumed when the sweetened condensed milk was fed was identical with that secured when the normal milk was used, namely 52 grams; but the composition of this gain is different in the one case as compared with the other as is indicated by the Calorie equivalents, 118 protein and 145 fat, 59 protein and 300 fat.

The evaporated milk group did better than did either of the other groups. The total gain in dry matter per kilo of dry matter consumed is 300 grams. A thousand food Calories ingested produced a gain of 182 grams, 61 grams of which were dry matter, containing a total of 377 Calories, 108 in the form of protein and 269 in the form of fat.

An extended discussion of the results in this table, furnished by the groups receiving calcium phosphate seems unnecessary. As a rule the gains were somewhat less in amount but were of the same general character as those of their mates. The effect of calcium phosphate upon the bones of the animals to which it was fed is further discussed on pages 82-85.

Referring to the starch equivalent or Calorie ratio, it will be seen that the production of one unit of gain required 4.01 units when the normal ration was fed, 2.79 when the evaporated and 2.93 when the sweetened ration was fed. The evaporated milk group made a very favorable showing in this particular and, taking into consideration the other results already discussed bearing on this food, it seems manifest that milk which has been heated and held at a temperature sufficiently high practically to sterilize it may be digested readily and assimilated by the young.

The efficiency of the sweetened milk as measured by the starch equivalent ratio, although of interest, has minor value because of the marked differences shown to have existed in the composition of the gain and the size and vigor of the animals resulting from its consumption.

PERCENTAGE UTILIZATION OF PHYSIOLOGICALLY AVAILABLE CALORIES

A study of the percentage utilization of the energy consumed by the three groups of animals reveals that whereas the normal milk lot retained only 26 percent as gain, 38 percent was retained by those fed evaporated milk and 36 percent by those fed the sweetened milk.

When calcium phosphate was added to the food the gains were 26, 31 and 32 percents respectively, being less in two of the three cases.

The results attained with the two sweetened condensed milk groups merit attention. The pigs utilized 57 and 55 percent of the protein Calories supplied in making body gain. Since 34 percent of the protein furnished was needed for maintenance, it follows that 91 and 89 percents of the protein fed were utilized. Apparently the ration might have carried properly a larger protein content. This high percentage usage is due to the very low protein content of the ration, 1.55 percent as compared with 3.57 percent in normal milk. The writers believe that no young and growing animal of any species should be required to utilize 90 percent of any food constituent for maintenance and growth, but that at least 25 percent more protein should be furnished than is thus needed, and that a yet larger percentage excess of carbohydrates should be supplied.

TABLE XXXVI—PERCENTAGE UTILIZATION OF PHYSIOLOGICALLY AVAILABLE CALORIES IN FOOD

	Normal milk				Evaporated milk				Sweetened condensed milk				Standard	
	Plain		Calc. phos.		Plain		Calc. phos.		Plain		Calc. phos.		Plain	
	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain
Total	23	26	21	26	24	38	23	31	21	36	21	32	19	36
Protein	17	53	16	44	21	53	20	49	34	57	34	55	13	32
Milk sugar														
and fat	24	19	23	21	25	34	24	26	19	33	19	30	21	37
Ash	..	50	..	54	..	51	..	61	..	67	..	87	..	23

The ash utilization is of interest since it shows that whenever calcium phosphate was added to the food an increased amount of ash was retained in the body. Whether it was derived from this added ingredient or whether its employment favored the utilization of the milk ash, does not appear. It should be noted, however, that when calcium phosphate was fed to the normal milk group, the increase in the ash utilization for body gain was only 4 percent; that when fed to the evaporated milk group, the gain was only 10 percent; but that an increased ash utilization of 20 percent was secured when the calcium phosphate was fed to the sweetened condensed milk group. The ration fed the latter group when calcium phosphate was omitted was

presumably deficient in ash, only 0.3 percent originally being present.

Table XXXVII, representing the percentage excess of the food over and above maintenance needs utilized for growth, indicates the efficiency of the several milks as producers of body gain after an arbitrary maintenance requirement has been deducted. The same relativity again appears; the high protein utilization of the sweetened condensed milk groups is still in evidence, 86 and 83 percents respectively of all the protein fed over and above maintenance needs being transformed into body tissue.

Tables XXXV and XXXVI indicate that the unsweetened evaporated milk was superior to the normal milk when measured in terms of efficiency. No reason occurs to the writers why such milk should not be used as food for the young provided the amount and composition of the gain produced is satisfactory; and the evidence afforded in these tables and in the clinical records as shown on pages 134-135 indicates such gains.

TABLE XXXVII—PERCENTAGE EXCESS FOOD OVER MAINTENANCE UTILIZED FOR GROWTH

	Normal milk			Evaporated milk			Sweetened condensed milk			Standard
	Plain	Calc.	Phos.	Plain	Calc.	Phos.	Plain	Calc.	Phos.	
Total	34	33		50	40		46	40		44
Protein	64	52		67	61		86	83		37
Fat	25	27		45	34		41	37		47

Tables XXXVI and XXXVII and the comments thereon indicate that the sweetened condensed milk ration furnished insufficient protein for the normal body growth of the young animal. Tables XXXVIII and XXXIX in still another way emphasize this same point. A decrease in protein to the extent of more than 100 Calories in a kilo in the gain made by the young pigs fed the sweetened product, is significant. It is due to the fact that only half the protein furnished in the other feeds was available to the use of this group; that, to phrase it differently, there was a marked decrease in protein percentage in the body gain even though 90 percent of the whole amount fed was utilized for maintenance and gain. A simple calculation from data already submitted will show that even if this group had conserved in the form of body gain all the protein provided and used none whatever for maintenance, which is of course a physiological absurdity, such an investment would not have equalled the gain actually conserved by the groups fed the normal and evaporated milks. The effect of calcium phosphate on the ash data again was manifested.

TABLE XXXVIII—CALORIES IN ONE KILO OF GAIN

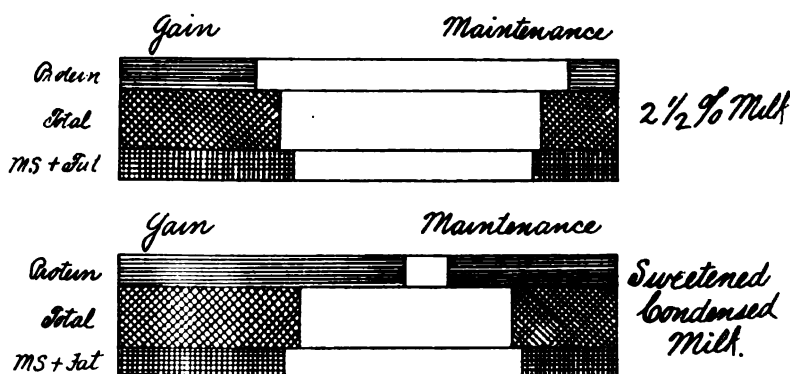
	Normal milk		Evaporated milk		Sweetened condensed milk		Stand- ard
	Plain	Calc. phos.	Plain	Calc. phos.	Plain	Calc. phos.	
Protein	642	639	593	552	443	453	480
Fat	788	1041	1482	1182	2251	2095	1750
Total	1430	1680	2075	1734	2694	2548	2230
Ash (grams).	30	39	30	36	26	34	22

TABLE XXXIX—CALORIES (AVAILABLE) IN ONE KILO OF FOOD CONSUMED

	Normal milk		Evaporated milk		Sweetened condensed milk		Stand- ard
	Plain	Calc. phos.	Plain	Calc. phos.	Plain	Calc. phos.	
Protein	139	139	128	128	60	60	188
Milk sugar ...	201	201	195	195	381	381	463
Fat	289	289	312	312	141	141	124
Total	629	629	635	635	582	582	775
Ash (grams).	7	7	6.7	6.7	3	3	9.8

The following graph, based on data shown in tables XXXVIII and XXXIX, illustrates the utilization of food constituents when abundance and when scarcity prevail. It tells its own story. The 2.5 percent milk, with a nutritive ratio 1:2.9, furnished a desirable ratio of protein to fat for construction purposes; but the sweetened condensed milk, nutritive ratio 1: 8.7, produced a gain rich in fat but seriously deficient in protein, and the animals consequently were lacking in vitality. The food of the young should possess the proper nutritive ratio. The need of a right relationship between the muscle and the fat contents of the infant body cannot be emphasized too strongly.

Percentage Utilization of Calories in Food.



GRAPH 9

Table XL displays the protein, milk sugar and fat ratios in the food consumed compared with the protein to fat ratios in the gains produced.

TABLE XL—RATIOS

	Protein	In food consumed			In gain			
		Milk	sugar	Fat	Protein	Fat		
Normal milk	1	:	1.4	:	2.1	1	:	1.2
Normal milk and calc. phos. ..	1	:	1.4	:	2.1	1	:	1.6
Evaporated milk	1	:	1.5	:	2.4	1	:	2.5
Evaporated milk and calc. phos.	1	:	1.5	:	2.4	1	:	2.1
Sweetened condensed milk....	1	:	6.4	:	2.4	1	:	5.1
Sweetened condensed milk and calc. phos.	1	:	6.4	:	2.4	1	:	4.6

The wide nutritive ratio of the sweetened condensed milk, due to the addition of cane sugar, is plainly evident, and the character of the resulting tissue is made apparent by the wide protein to fat ratios, 1: 5.1 and 1: 4.6.

It should not be inferred that the writers underestimate the value of sweetened condensed milk. It possesses much food value. Undoubtedly it serves an admirable purpose as a source of heat energy in more mature life and probably contains a sufficiency of protein for its maintenance. They hold, however, that it is not well adapted to the indiscriminate feeding of young, growing animals, including the human. A body frame well covered with muscle and not overburdened with fat should be the object sought in feeding the young of any species. Neither this nor any other milk food with a similarly wide nutritive ratio, 1: 8.5, is suited for use at this early period of development. The writers' personal observations on this point, it may be well to state, are not confined to the study of the records of these pigs but include as well a survey of its use in the feeding of the human infant.

CONCLUSIONS

1. Both evaporated milk and sweetened condensed milk are digested readily and assimilated and their nutrients appropriated for tissue growth.

2. Evaporated milk compared very favorably indeed with normal milk standardized to a medium fat percentage, in nutriment and in tissue production.

3. In the trials now under consideration sweetened condensed milk, though showing an abundant nutritive efficiency as measured by energy units, proved an undesirable food for the growing young,

for the reason that its nutrients are proportioned so as to produce a weak and dangerously fat body.

4. Although not as yet discussed it seems pertinent briefly to state at this point that the strength of the bones of the pigs fed normal evaporated and sweetened condensed milk was affected by the character of their rations. When the sweetened ration was used, the bones were but two-thirds as strong as were those produced on normal milk; and the bones of those animals nourished on evaporated milk lacked to some extent the strength of those produced on normal milk. The details of the trial on which this statement is based appear in the following section.

XI. FOOD EFFECTS ON SKELETAL STRUCTURE

The question of the effect of food upon the strength of the bone of any animal is of vital interest, particularly because of its relation to rickets and other evidences of malnutrition in children.

CONCERNING RACHITIS (RICKETS)

During the trials discussed in the preceding pages it was observed that under certain conditions the pigs developed lameness or showed an indisposition to remain standing. Farmers of the Middle West long have known that over-fat and weak animals are produced when corn is their sole diet. Some of our experimental animals consuming milk which, like corn, is rich in its carbohydrate and fat contents but relatively poor in ash and protein, developed a condition resembling rickets. Realizing the primary need of a strong body framework and that such can be produced only from the ash in the food consumed, the amount of ash in the ration was increased by the addition of calcium phosphate in order to note its effect on the composition of the animal and the strength of its bones.

The service of protein, carbohydrates and fat in animal nutrition has been studied exhaustively, but relatively the study of the ash requirements of the body has been neglected until of recent years.

Rickets (59; 19, pp. 35, 37, 38), a disturbance of early childhood, is a condition resulting from malnutrition of the bones. Although known from the earliest days, there is reason to believe that this disease now is more prevalent than formerly, and that from one-third to nine-tenths of the infants of Southern Europe and Asia are its victims. The artificially fed infants of London particularly are prone to this malady and, though gypsies are said to be relatively free from this

trouble, other Caucasians are especially affected, (59, p. 238). Spiet-schka estimates that 5 percent of all babies are affected with congenital rickets, basing his statement on observations of 1,468 cases. If a child reaches the age at which it can utilize solid food without developing this malady, its liability to an attack is slight, but no animal at any age seems entirely immune from it.

In some regions, as the Hawaiian Islands and South Africa, the roughage is said to be so deficient in ash that horses are fed some specific adjunct in order to strengthen their skeletal structure. For the same reason, corn-belt farmers feed their pigs mixtures of wood ashes, bone meal, charcoal, salt and soil. Certain of these materials as well as tricalcic and other lime phosphates have been fed experimentally with the result that animals have been found to possess the power of absorbing various inorganic substances. It has been shown in some cases that the composition, density and strength of the bones have been improved by such feeding (10, 24).

The influence of the ash content of the food of mother pigs upon their young has been shown recently at the Iowa station (17). The results indicated that the food had a marked influence upon the strength of the young and the number in the litter.

In view of the information now available it seems absurd to hold that "inherited predisposition" is the cause of rickets. Heredity may be a factor in some cases, but if an infant's bones seem deficient and poorly developed, it is likely to be due to the malnutrition of its mother prior to or subsequent to its birth, caused by the lack of a sufficient supply of calcium and phosphorus in the mother's food to meet her own body needs and at the same time to furnish material for the construction of a strong body framework for the child. Apparently "congenital rickets" soon will be held to be the result of a marked deficiency in bone forming elements in the mother's food, and "acquired rickets" to be the consequence of an actual or relative deficiency in the ash of the child's food. Many foods carrying large percentages of starch, sugar or fat contain too little ash to meet the needs of the rapid body growth induced by plentiful supplies of carbohydrates and fat.

A loss of calcium occurs usually when "modified milk," a high fat and low protein food, is used. Too much fat and milk sugar are present in proportion to the protein. The undue call made upon the bases in the neutralization of the fatty acids liberated by the intestinal cleavage of the excess of fat which to a considerable extent is voided as soaps, limits the amount available for purposes of construction, thus ag-

gravating the tendency toward rickets. This tendency of high fat foods to induce a rachitic condition as well as constipation is ably discussed by Czerny and Steinmetz (14, pp. 122-137). This view agrees with the observations that rickets are more prevalent among bottle-fed babies than among those fed naturally, that most cases occur during the first three or six months of a child's life, and that the symptoms gradually disappear as the child becomes able to digest solid food. In this connection, moreover, should be noted the remarks in this bulletin on pages 98 to 100 touching fat digestion.

At this point it should be said that whereas at one time an impression obtained that the continued use of pasteurized milk might tend to induce a rachitic condition in children, owing to the alleged lessened soluble ash content resulting from such a treatment, there seems reason to believe that the commercial pasteurization of milk as now conducted does not precipitate enough ash to induce rickets in the children consuming the pasturized product, and that the low temperatures used do not coagulate enough albumen appreciably to impair its value for this purpose (54).

BREAKING STRENGTH TRIALS

Throughout most of these trials the femur of the right leg was removed, air dried to constant weight, and its breaking strength determined. Plate VIII pictures the machine used and also portrays variations in the form of femur of pigs of the same litter. The mechanism was rather large for this kind of work, but it was possible to work within an error margin of 10 pounds.

Lime in the form of tri-calcic phosphate was added to the food of certain pigs in order to determine its effect on the body composition as is set forth on pages 69 to 79. Difficulty was experienced in inducing the pigs to consume known amounts. Finally it was fed suspended in gum tragacanth.¹ This test was conducted in conjunction with that of the condensed milks. All the pigs remained in excellent health throughout the 49 days of test and in every instance were capable of furnishing satisfactory data.

The added lime apparently tended to retard the deposition as body gain of protein and fat by the evaporated milk group, but no such effect was observed with the normal milk-fed animals. In every in-

¹Gum tragacanth, 25 grams in two quarts of water, holds in suspension 180 grams of calcium phosphate. Two quarts of this suspended matter contained approximately 30 "spoonfuls," each carrying 4.6+ grams of tri-calcic phosphate. It was fed at the rate of one gram phosphorus daily to each 10 pounds body weight. Since the phosphorus content of the tri-calcic phosphate is approximately 20 percent, two spoonfuls furnished two grams of phosphorus, an amount sufficient for a 20 pound pig.

stance a material increase of the ash content of the body occurred. The animals fed lime and sweetened condensed milk laid on a little more protein, but fat absorption apparently was retarded. These were not marked effects, as may be seen from a study of the longitudinal sections (see Plate VII, p. 64). Nos. 148, 155 and 162, fed on normal 3 percent milk plus calcium phosphate, clearly were smaller than the three fed the same milk without the phosphate. A less marked difference appeared when the evaporated milk was fed. However, the six pigs fed sweetened condensed milk were neither as well grown nor as firm fleshed as their companions on normal milk; yet the three fed calcium phosphate were nearly if not quite as well grown as those not thus fed. The pigs comprising the evaporated milk group were sturdier, firmer fleshed animals than those in the sweetened condensed milk group. The influence of calcium phosphate on their growth does not stand out, but is readily seen if table XLI is carefully studied.

TABLE XLI—COMPOSITION AND BREAKING STRENGTH OF FEMUR AS INFLUENCED BY CALCIUM PHOSPHATE (THREE PIGS USED IN EACH CASE)

		100 parts protein and ash contain		Ratio protein to ash 1:	100 parts ash con- tain		Breaking strength lbs.	Average Increase from use of cal- cium phosphate	
		Protein %	Ash %		Lime %	Phosphoric acid %		lbs.	%
Normal	Plain	50.4	49.6	0.98	51.5	42.0	297	...	..
	Calc. phos. ...	45.7	54.3	1.19	52.1	42.1	427	130	44
Evap.	Plain	52.5	47.5	0.90	50.6	41.4	263	...	..
	Calc. phos. ...	48.8	51.2	1.05	51.4	42.3	453	190	72
Sw. Cond.	Plain	51.5	48.5	0.94	51.6	42.6	200	...	..
	Calc. phos. ..	45.9	54.1	1.18	52.3	41.9	287	87	43
Average	Plain	51.5	48.5	0.94	51.2	42.0	253	...	..
	Calc. phos. ..	46.8	53.2	1.14	52.0	42.1	389	136	54

An attempt is made in this table to show the effect of the calcium phosphate in the food on the composition of the skeleton. The results are based on the analyses and breaking strengths of the femur bones of the several animals. In every instance where lime was not fed, 100 parts protein and ash in the femur contain more protein than ash, the ratio being 1:0.98, 1:0.90 and 1:0.94 for each group, with an average for the nine pigs of 1:0.94. When calcium phosphate was fed the reverse was true, the protein content being less than that of the ash, the protein to ash ratios being 1:1.19, 1:1.05 and 1:1.18 respectively,

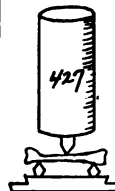
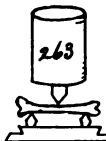
with a nine-pig average of 1:1.14. Whenever the calcium phosphate was fed, 100 parts of ash contain more lime than when it was omitted. The average difference amounts to 0.8 percent, or a percentage increase of 1.56 percent.

The phosphoric acid content of the bones on the other hand, increased when normal and evaporated milks were fed and decreased when sweetened condensed milk was used. The average increase was only 0.1 percent, but this is equivalent to an increase of 0.25 percent.

It is significant that the testimony of each of the nine pigs from three litters fed different rations is in agreement. The writers believe that this fact warrants the statement that the added phosphate of lime probably contributed to bone construction.

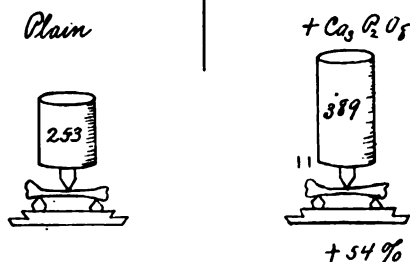
The record of the breaking strengths of the several femur bones affords striking evidence of the effect of the addition of calcium phosphate. In the columns headed "breaking strength" it will be seen that whenever calcium phosphate was fed the strength of the femur of the

Breaking Strength of Femur

<i>Normal Milk</i>		<i>Evaporated Milk</i>		<i>Sweetened Condensed Milk</i>	
<i>Plain</i>	$+Ca_3P_2O_8$	<i>Plain</i>	$+Ca_3P_2O_8$	<i>Plain</i>	$+Ca_3P_2O_8$
					
	+44%		+72%		+41.5%

Summary

Normal, Evaporated and Sweetened Condensed Milk



GRAPH 10

animals increased—normal milk group 130 pounds, or 44 percent; evaporated milk group 190 pounds, or 72 percent; sweetened condensed milk group 87 pounds, or 43 percent. Furthermore, the average breaking strength of the femurs of the three animals fed sweetened condensed milk without lime was only 200 pounds, while the record afforded by the normal group was 297 pounds. In other words, the bones of the animals which lived largely on sweetened food were but two-thirds as strong as the bones of those which had eaten plain normal milk and only three-fourths as strong as the bones of the pigs on the evaporated milk group.

On the average 136 pounds more weight were required to break the femur when the calcium salt was added to the ration. This is equivalent to a 54 percent increase. The variation between individuals was not great, but the classes stand out distinctly. Apparently the strength of the bone may be fortified by supplementary feeding from inorganic sources, a matter of more than academic interest. Graph 10 clearly sets forth these points.

The writers believe that too much calcium phosphate was fed in these trials, since it seemed injuriously to affect the general thrift of the animals. It is not claimed that it is desirable to feed calcium phosphate to infants. This trial, however, clearly indicates the need of an ample supply of ash ingredients in the food. If for any reason it becomes necessary to feed a child for a time on sweetened condensed milk or any other low-ash food, the lime and phosphorus present may be advantageously fortified by the addition of some substance, preferably organic, rich in these elements.

In this connection may be recalled the tests made by Hart, McCollum and Fuller (24) wherein the breaking strength of the pig femurs was materially affected by the feeding either of inorganic or of organic phosphorus; and Burnett's work (10) wherein it was "conclusively proven" that "food rich in phosphates and mineral matter will increase the strength of bone."

CONCLUSIONS

1. The femur of the average pig fed sweetened condensed milk was but two-thirds as strong as that formed when normal milk was fed.
2. Only a slight difference appeared between the normal and the evaporated milk groups in regard to the breaking strength of their femurs, but this difference favored the normal product.
3. In spite of the high ash percentage utilization by the pigs fed sweetened condensed milk, their body gain contained less ash than did

the gains of either the normal or the evaporated-milk-fed-animals.

4. Tricalcic phosphate does not seem to be a particularly available form in which to furnish lime and phosphoric acid.

5. The tricalcic phosphate probably was used in two ways. Small amounts may have contributed directly to the body growth; and its presence may have allowed more of the original ash in the several foods to be utilized, by supplying what might otherwise have been needed for the saponification of fat in the food.

XII. DILUTE OR CONCENTRATED RATIONS

ENERGY VALUES AFFECTED BY DILUTION

It was noted during the course of the trials reported on pages 82-85 that those pigs which ate the relatively dilute skimmilk gained less rapidly in weight and retained a smaller percentage of the food units they consumed than did the animals fed milks of medium and high fat contents; and the question naturally arose whether this was or was not due to the dilute nature of the skimmilk ration.

The effect of dilution on the utilization of protein, milk sugar and fat is a pertinent matter. It is evident that a larger bulk of a dilute food must be consumed in order to secure a given amount of dry matter than of a more concentrated ration. Will increased dilution tend to prevent the consumption of an amount of food sufficient to produce normal body growth? Will an excessive amount of water cause a reduction in food Calorie utilization and an increased expenditure of energy? It seems probable that this consideration has bearing on the results previously discussed. For example, it is in evidence in the trials of skim-, 2.5 and 5 percent milks and of the "standard" ration. The pigs fed skimmilk ingested 343 kilos while those fed on the standard ration consumed but 150 kilos; and yet these widely varying bulks of food contained practically the same total Calorie equivalents though differing greatly in their components.

In the early days at this station, Hills (27) studied this question and found that the pigs fed the more concentrated ration ate more and gained more than did those fed a dilute ration, but made no better use of their food as a result of their richer diet; indeed, it took more dry matter to make a pound of gain in live and dressed weights when the more concentrated ration was fed than when the dilute diet was supplied. However, this was not as closely controlled a test as the one now under consideration.

In order to secure further information as to the effect of the dilu-

tion and energy of the food as reflected in the body tissue which is stored by growing animals, the following series of trials was instituted. Three pigs, one from each of three litters, were fed for 51 days normal grade Jersey herd milk, which was so standardized as to contain 12 percent solids and 2.5 percent fat; three others received a similar grade of milk to which water was added in amounts sufficient to reduce its total solid contents to about 9 percent; and two more consumed skim-milk carrying 9.8 percent total solids. Subsoil earth was eaten freely by each pig. If the question were one of chemical composition only, and provided equal amounts of total solids were consumed, similar results in body growth might be expected whether normal milk or the diluted product were fed. The results are presented in the following tables.

Table XLII shows the effect of the food consumed on the composition of body gain. In addition to the results secured in this particular trial the data obtained when feeding the animals used as standards are presented for purposes of comparison. These have no immediate relation to the dilution factor but have a direct bearing on the question of energy consumption, the two rations practically being similar in their moisture contents while varying chiefly in their fat contents.

TABLE XLII—EFFECT OF FOOD ON COMPOSITION OF BODY GAIN
(51 days feeding)

	Weight Kilos	Water %	Dry matter %	Ash %	Protein %	Fat %	Milk sugar %	Nutri- tive ratio 1:	Ratio protein to fat 1:	Daily gain Total grams	Dry matter grams
THREE PIGS FED 2.5 PERCENT MILK											
Food ..	157.3	87.93	12.07	0.76	3.76	2.63	4.89	2.85	...	...	...
Gain ..	12.11	67.68	32.32	3.01	14.89	14.38	...	...	0.97	237	77
THREE PIGS FED 2.5 PERCENT MILK AND WATER											
Food ..	178.0	90.92	9.08	0.58	3.01	1.89	3.60	2.60	...	...	...
Gain ..	10.24	68.75	31.25	3.72	16.18	11.23	...	...	0.69	201	63
TWO PIGS FED SKIMMILK											
Food ..	165.8	90.20	9.80	0.75	3.97	0.03	5.05	1.29	...	...	...
Gain ..	9.68	77.75	22.25	3.22	15.46	2.61	...	...	0.17	190	42
THREE PIGS "STANDARD-FED" SKIMMILK AND GRAIN											
Food ..	148.2	79.00	21.00	0.99	5.56	0.41	14.04*	2.69	...	...	...
Gain ..	16.64	68.45	31.55	2.27	11.96	16.54	...	...	1.38	333	105
THREE PIGS, "STANDARD-FED," 2.5 PERCENT MILK AND GRAIN											
Food ..	150.7	78.83	21.17	0.97	5.20	2.67	12.33*	3.53	...	...	...
Gain ..	20.41	63.65	36.35	2.21	11.50	20.98	...	...	1.82	408	148

*Includes carbohydrates of the grain adjunct.

The pigs receiving 2.5 percent milk, 2.5 percent milk plus water, and skimmilk, ingested 157, 178 and 166 kilos respectively. There was but little difference in the percentages of dry matter retained as gain by the first two groups, but the composition of these gains was unlike. The gain in body tissue produced when undiluted milk was fed was almost exactly half and half protein and fat whereas the diluted food produced a gain much richer in protein than in fat, as is indicated by their ratios of 1:0.97 and 1:0.69. The skimmilk-fed animals made a watery gain, laid on much protein and but little fat, indicating a higher tolerance for protein than for milk sugar. Gross gain in weight is but a rough index of the nutritive value of milk foods, as it may be influenced greatly by mere preponderance of water throughout the body tissues.

The effect on the body gain of the increased energy furnished by the fat in the food is set forth in the lower portion of the table. The amounts of food consumed and their dry matter contents are almost identical for each group. The differences observed in body growth are due to the increased amount of fat contained in the food ingested by the second group. The effect of fat plainly is seen in the increased retention of dry matter and of fat.

The average gain in gross weight made by these groups from week to week is shown in table XLIII.

TABLE XLIII—PERCENTAGE GAINS

	Initial weight kilos	Percentage 7 days	14 days	21 days	28 days	35 days	42 days	49 days
2.5% milk	9.32	1	8	17	35	63	92	125
2.5% milk and water.....	10.01	—1	4	11	26	49	73	102
Skimmilk	8.85	3	8	17	34	57	79	110
Standard; skimmilk and grain	8.06	8	16	36	77	116	155	206
Standard; 2.5 % milk and grain	8.46	11	26	57	95	140	181	241

The weekly percentage increases in live weight were quite uniform in the 2.5 percent milk and skimmilk-fed animals during the first four weeks, after which time the pigs fed the richer ration outstripped their competitors. The pigs fed the diluted milk made the smallest percentage gains throughout the feeding period. Since they were heavier at the start, the gross gain made was greater than that made by the skimmilk group but was less by nearly two kilos than that made by the

2.5 percent milk groups. The gain made by the skimmilk group was very watery (see table XLII). The larger gains made by the pigs fed the standard rations are shown for purposes of comparison.

A summary of the results showing actual gains, available calories fed, starch equivalents and other comparisons based on the food consumed and its relation to the growth of the animals, is given in table XLIV, together with corresponding data for the standard-fed animals.

The gradually decreasing amounts of calories consumed by the first three groups (line 5) is to be noted. It will be remembered that the total bulks of food ingested were 157, 178 and 166 kilos respectively. The grams of gain per kilo of food (line 6) were 77, 58 and 58, but the dry matter gains per kilo of dry matter in the food (line 7) were 206, 198 and 133 grams respectively. The latter figures represent true food utilization and are proportional relatively to the nourishment supplied other than the water.

TABLE XLIV—GROWTH OF YOUNG PIGS

	2.5% milk	2.5% milk + water	Skimmilk	Standard; skimmilk and grain adjunct	Standard; 2.5% milk and grain adjunct
1 Initial weights, kilos	9.32	10.01	8.85	8.06	8.46
2 Final weights, kilos	21.23	20.25	18.53	24.70	28.87
3 Gain, kilos	12.11	10.24	9.68	16.64	20.41
4 Percentage gained	130	102	109	206	241
5 Available Calories fed.....	89470	75300	58620	105100	126600
6 Total gain per kilo of food consumed, grams	77	58	58	112	135
7 Dry matter gained per kilo dry matter consumed, grams	206	198	133	190	257
8 Gain per 1,000 Calories consumed, grams	135	136	165	158	161
9 Gain in dry matter per 1,000 Calories consumed, grams	44	42	37	50	59
10 Calories re- : tained as : Total	262	231	144	319	388
growth per : as protein .	83	90	104	78	76
1,000 Calo- : as fat	179	141	40	241	312
ries fed :					
11 Starch equivalent or Calorie ratio 1:	4.01	4.55	7.29	3.30	2.71
12 Ratio, protein to fat in gain, 1:	0.97	0.69	0.17	1.38	1.82
13 Nutritive ratio of food, 1: .	2.85	2.60	1.29	2.69	3.53

Lines 8, 9 and 10 show how the pigs utilized 1,000 food Calories. The 2.5 percent milk animals gained 135 grams, 44 of which were dry substance containing 262 Calories, 83 as protein and 179 as fat. The 2.5 percent milk plus water group gained 136 grams containing 42 grams dry matter equivalent to 231 Calories, 90 as protein and 141 as

fat. The skimmilk class for every 1,000 Calories consumed gained 165 grams containing only 37 grams dry matter which carried 144 Calories, 104 as protein and 40 as fat. As great a total gain followed the use of diluted as of undiluted milk (136 and 135 grams), but the protein storage was increased slightly and the fat storage lowered considerably following dilution.

The starch equivalents (line 11) show that the general conservation of the food consumed was 4.01, 4.55 and 7.29 respectively for the three groups. These figures, while what might have been expected, perhaps indicate inefficient utilization. It is evident that considerations both of dilution and energy should be taken into account. While the diluted 2.5 percent milk ration produced gain more economically per unit of energy consumed than did the skimmilk group, yet both failed to attain the efficiency secured when the undiluted milk served as food.

The data in the last columns afforded by the records of the standard-fed pigs are indicative of what may result from energy differences in food supplies, dilution being constant. This point is brought out to the best advantage in line 10. The skimmilk and the grain adjunct group retained as growth per 1,000 Calories fed, 319 Calories, 78 of which were protein and 241 fat, whereas the group fed 2.5 percent milk and the grain adjunct retained 338 Calories, 76 of which were protein and 312 fat. This difference in favor of the latter group may be attributed safely to the larger amount of fat in its ration.

Table XLV displays food utilization expressed on a percentage basis, including not only the percentages actually retained in the form of body gain but also a calculated maintenance requirement, previously explained on page 42.

The normal milk, diluted milk and skimmilk groups respectively utilized 26, 23 and 14 percents of their Calories. The two groups fed the standard rations conserved 32 and 39 percents of the total Calories. The protein utilization by the skimmilk-fed animals was much less than that of their mates fed on the other milk rations—24 as compared with 32 and 33.

TABLE XLV—PERCENTAGE UTILIZATION OF PHYSIOLOGICALLY AVAILABLE CALORIES IN FOOD

	2.5% milk		2.5% milk and water		Skim milk		Standard ; skim milk and grain		Standard ; 2.5% milk and grain	
	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain	Maintenance	Gain
Total	22	26	26	23	30	14	20	32	18	39
Protein	14	32	16	33	12	24	12	28	14	35
Milk sugar and fat ..	25	24	29	20	44	7	23	33	20	40
Ash	..	30	..	37	..	25	..	26	..	31

The group fed normal milk utilized 24 percent, and that fed the diluted milk utilized 20 percent of the available milk sugar and fat Calories. The skim milk group utilized only 7 percent. Since the latter ration practically was fat free, this must have been derived from the milk sugar. Clearly these animals exhibited a low tolerance for this constituent.

The two standard rations do not illustrate the effect of dilution but show clearly that an increase of a moderate amount of fat in the food consumed is followed by an increased Calorie utilization in body growth.

Table XLVI shows the percentage excess of food over maintenance utilized for growth, the Calories required for maintenance being eliminated. The data indicate the same relative utilization throughout the several groups as that just considered.

TABLE XLVI—PERCENTAGE EXCESS FOOD OVER MAINTENANCE UTILIZED FOR GROWTH

	2.5 percent milk	2.5 percent milk and water	Skim milk	Standard ; skim milk and grain	Standard ; 2.5 percent milk and grain
Total	33	31	20	40	48
Protein	37	39	27	32	41
Fat	32	28	13	43	50

The following tables, XLVII and XLVIII, show the Calories in one kilo of gain and in one kilo of the food consumed. They serve to bring out the fact that the gain of the groups fed 2.5 percent milk plus water was extremely rich in protein even though the protein Calorie content of this ration was rather low. It apparently indicates that a reasonable amount of dilution may tend to increase protein utilization.

The two grain adjunct rations are shown to vary chiefly in their fat Calories and this is reflected in the gain by the marked increase

of 409 stored fat Calories resulting from the feeding of the 2.5 percent milk ration plus the grain adjunct, as compared with the skim-milk ration plus the grain adjunct.

TABLE XLVII—CALORIES IN ONE KILO OF GAIN

	2.5 percent milk	2.5 percent milk and water	Skim milk	Standard; skim milk and grain	Standard; 2.5 percent milk and grain
Protein	611	663	634	490	472
Fat	1327	1036	241	1526	1935
Total	1938	1699	875	2016	2407
Ash (grams) ..	30	37	32	23	22

TABLE XLVIII—CALORIES (AVAILABLE) IN ONE KILO OF FOOD CONSUMED

	2.5 percent milk	2.5 percent milk and water	Skim milk	Standard; skim milk and grain	Standard; 2.5 percent milk and grain
Protein	155	123	163	194	183
Milk sugar	200	148	207	492	435
Fat	243	174	3	23	222
Total	598	445	373	709	840
Ash (grams) ..	7.6	5.8	7.5	9.9	9.7

The results may be expressed on a nutritive ratio basis as follows:

TABLE XLIX—RATIOS

	In food consumed			In gain		
	Protein	Milk sugar	Fat	Protein	Fat	
2.5 percent milk	1	: 1.3	: 1.6	1	: 2.2	
2.5 percent milk and water ...	1	: 1.2	: 1.4	1	: 1.6	
Skim milk	1	: 1.3	: 0	1	: 0.4	
Skim milk and grain	1	: 2.5	: 0.2	1	: 3.1	
2.5 percent milk and grain....	1	: 2.4	: 1.2	1	: 4.1	

The protein to milk sugar ratios in the first three lines are quite similar and the protein to fat ratios in the first two lines also agree closely. The second named ration contained more water than the first. It would appear that the differences in the nature of the gain justly may be ascribed to dilution and to whatever variation occurred in the quantity of food nutrients consumed. On the other hand, comparing the artificially diluted with the skim milk ration, the marked differences in the nature of the growth secured seem attributable not to dilution, for they were essentially alike in this particular, but to the increased energy present in the artificially diluted ration in the form of fat.

Similarly the grain adjunct rations indicate differences in body growth that are attributable mainly to the energy content of the ration and not to the dilution. Thus with similar protein to milk sugar ratios but with widely different fat ratios, the ration carrying the larger fat percentage produced a body gain likewise richer in fat.

This may be stated differently, and perhaps more succinctly, in the following manner. For every 1,000 Calories consumed by one group or the other, when associated with a greater or less amount of water, certain body substance gains were made, expressed as Calories.

TABLE L—CALORIE STATEMENT

Group	Calorie consumption				Water usage grams	Body gains, ex- pressed as Calories		
	Protein	Milk sugar	Fat	Total		Protein	Fat	Total
2.5% milk	259	+ 335	+ 406	= 1000	1468	83	+ 179	= 262
2.5% milk and water	276	+ 333	+ 391	= 1000	2042	90	+ 141	= 231
Gain or loss resulting from use of the more concentrated ration	-17	+ 2	+ 15	= 0	-574	-7	+ 38	= + 31

The distribution of food Calories is seen to be quite similar, the decrease of 17 Calories of protein in the normal milk being offset by an increase of 2 Calories of milk sugar and 15 fat Calories. An increase of 31 Calories occurs in the growth secured when 2.5 percent milk was fed, resulting from a loss of 7 protein Calories and a gain of 38 fat Calories. Dilution may be somewhat responsible for this situation, since it had been shown that 574 grams less water was associated with the food Calories producing the greater gain.

Calculating this data on a basis of Calories associated with every 1,000 grams of water consumed, the following statement may be presented.

TABLE LI—CONSUMPTION AND GROWTH

	Total	Calories consumed			Retained as growth		
		Protein	Milk sugar	Fat	Total	Protein	Fat
2.5 percent milk	681	176	228	277	178	56	122
2.5 percent milk and water	490	135	163	192	113	44	69
	+191	+41	+65	+85	+65	+12	+53

This indicates that, as between a 2.5 percent milk and a 2.5 percent milk plus water when equal quantities of water were consumed, the normal ration carried 191 more Calories, 41 of which were de-

rived from protein, 65 from milk sugar and 85 from fat, which resulted in an increase of 65 Calories in the body gain, 12 as protein and 53 as fat.

CONCLUSIONS

1. The theory that the ingestion of more water than is needed tends to lessen the food value of a ration seems sound.

2. In view of the fact that the milks were not heavily diluted, the writers do not feel justified in speculating as to what might have happened had an excessive amount of water been added to a milk of a medium fat content.

3. The results of these limited trials, while indicative, do not warrant definite conclusions.

XIII. THE DIGESTION OF MILK

Milk is coagulated by the action of rennin and pepsin a few minutes after it reaches the stomach. This process is hastened by the presence of hydrochloric acid in the stomach as well as by the lactic acid of the milk. The casein is digested for the most part in the stomach, being coagulated and, later, transformed into soluble forms—peptones and the like—by the stomachic enzymes. The fat for a while is held mechanically in the sponge-like fibrous mesh of the clotted casein and, when freed therefrom by casein digestion, passes on into the intestine where it becomes emulsified and by enzymic action is cleaved into glycerin and fatty acids, to be resorbed in the main and eliminated in part. The albumen, neither coagulated nor mechanically entangled, in watery solution together with much of the ash and practically all the milk sugar, forming the so-called whey, is forced from the curd mass by its contraction and passes on into the intestine, along which canal the solution percolates until digested and resorbed.

CASEIN DIGESTION

Chapin tells us that infants less than 10 months old find difficulty in digesting more than 1.5 to 2 percent cow's milk casein (13). Brenne-mann on the contrary, as quoted by Hall, says that milk protein "seems to offer the least trouble of any food element both in digestion and metabolism" (8, p. 177) and adds that it is the fat that causes the trouble. Czerny (14) has shown that if infants are fed on fat-free cows' milk, even though it is undiluted and contains 3.5 percent protein.

no traces of casein are found in the stools. This leads us to say that one child under observation in connection with these trials was consuming cows' milk so modified as to contain 5 percent of fat and only 1 percent of protein. Curds which it vomited contained on analysis 45.25 percent protein and 36.82 percent fat. The so-called casein curds from the stools of the same child proved on analysis to contain only 18.8 percent protein and were composed largely of fat. This child digested its food fairly well but developed rickets. Hutchinson (29) says that prepared casein is digested with ease and absorbed almost in its entirety. Furthermore buttermilk, which contains very little fat but from 3 to 3.5 percent protein, is digested readily. Indeed buttermilk has been used for years by Dutch peasants as a food for their infants even when they are ill. Carpenter (12) reports concerning his successful use of buttermilk in infant feeding, attributing it to "the great ease with which the proteid of buttermilk is digested." It will be news to many that there are mothers in this country successfully rearing their babies on buttermilk preparations (see pages 117-119).

Casein digestion as affected by the fat content. Stomachic digestion is retarded relatively by the presence of an over-large fat content in milk (21, p. 30). The flow of the digestive juices is not stimulated and protein digestion is less rapid and complete (51, vol. 3, p. 842). Schereschewsky (48) says that this inhibitory action is caused by the formation of a firm mat, whereas skimmilk coagulums are more flocculent. This observation is not borne out by the results of our trials using baby pigs, as evidenced by the examination of a hundred or more stomachic contents at intervals varying from a few minutes to five hours after the ingestion of the milk. Indeed, skimmilk forms a relatively tough, hard mass in the stomach, whereas the curd derived from milk containing fat always is more mellow and friable; and the richer the milk, the more tender the curd. However, the motion of the pig's stomach never was shown to be vigorous enough to break the curd mat. In fact, the condition and texture of the curds derived from fat milk as compared with lean milk essentially were the same, whether the curd mass was formed within or without the stomach. In other words, the initial process which takes place in the ordinary cheese vat is closely akin to the early stages which occur in normal milk digestion. Indeed, the curd mass was removed from some of these stomachs, compacted and kept for several days. During this time invariably it took on the character, odor, color, and texture of ordinary cheese in the process of making.

In this connection the mechanical effect of such materials as fine starch grains and the larger granules of dry earth upon curd formation is of interest. These substances when added to the milk, tended to prevent the formation of a firm curd mass. Indeed, when fed in considerable quantity, the fluidity of the milk was almost maintained and comfort and ease of digestion were promoted.

Clean subsoil earth was fed freely and daily to most of the experimental pigs. The larger part gravitated to the lower portion of the stomach before the milk coagulated sufficiently to entangle it, some of it adhered to the edges and sides of the curd clot, and little or none penetrated to the interior of the clot. The exterior curds which contained grains of earth seemed to disintegrate into fragments more readily than those which contained none.

No harmful results were noted with pigs when a firm curd of skim-milk formed in the stomach; yet an excess of fat in the food clearly was deleterious.

EFFECT OF COLLOIDS ON CURD STRUCTURE

It has been stated, especially by interested commercial concerns, that the addition of colloidal substances to milk prevents the formation of unduly hard curd masses, thus indirectly enabling the infant or other animal consuming such milk to digest it with greater ease and with less likelihood of digestive disorders. In order to test this matter, trials were made using 2.5 percent milk and three colloidal materials, gelatin, gum tragacanth, and eggs.

Gelatin.—Normal 2.5 percent milk, and the same milk to which was added a liberal quantity of gelatin, were fed to two pigs in their final meal before slaughter. No noticeable difference between the curd masses appeared either to the eye or to the touch. One of the writers, knowing which was which, at first thought that the gelatin curd was slighter more mellow and less tenacious than the other, but members of the station chemical force associated with him in this study could detect no difference.

Gum tragacanth.—This colloid, after having been reduced to a semi-fluid mass, was mixed with milk and fed to a pig. On slaughter, the curd mass proved to be somewhat softer and more mellow than normal.

Egg.—An egg was beaten into 1.5 pints of 2.5 percent milk and fed to a pig. On slaughter, it was found that the resulting curd was perceptibly more mellow than the curd in the stomach of the pig fed a

similar portion of normal milk as a check. It would appear that the digestibility of the curd mass might be thus modified. Further studies along this line are contemplated.

EFFECT OF CEREALS ON CURD STRUCTURE

In order to test the effect upon the firmness of curd masses of finely ground cereal, which in this instance consisted of corn meal, brown middlings and linseed oil meal, a reasonable quantity was mixed thoroughly with milk and fed to certain pigs some little time before death. Examination at the time of slaughter showed that the cereal particles thoroughly permeated the minute curd particles, whereas when milk alone was fed a somewhat denser curd appeared; in fact the stomachic contents actually were fluid, even though plenty of time had elapsed for curd formation if such could have taken place. The results of this test concerning the effect of the use of cereal as a means of preventing the formation of hard curd masses, bear out pediatric experience.

RATE OF COAGULATION IN THE STOMACH

Several tests were made to determine the length of time ordinarily required for the milk to coagulate after its consumption, the animals being specially fed just before slaughter. A portion of the usual allowance of milk was highly colored and fed to the pigs; then, after varying lengths of time, more milk differently colored was fed similarly. Two colors (normal milk and milk with butter color) were fed one minute apart and the stomachic contents were found thoroughly blended, indicating that coagulation had not occurred within a minute's time but that the stomachic action had been vigorous enough intimately to mix the fluids. When the two lots were fed at five minute intervals, one normal and the other colored with ultramarine, lumps of the differently colored curds were intermingled, the mass being solid but unevenly colored. When normal milk and milk highly colored with butter color were fed ten minutes apart, the curd formed from the second portion of milk merely surrounded that formed from that first fed, each color having coagulated distinct from the other. The second portion, instead of lying above the first, as it should have done, according to some physiologists, or being thoroughly mixed with it, had enveloped it completely to a depth which was almost uniform. Another trial afforded identical results after a 20-minute feeding interval.

Another pig was fed during the early evening with skimmilk strongly colored green. The next morning, the following evening and the second morning, it was fed as usual on normal skimmilk. When slaughtered, 39 hours after receiving the green milk, about two ounces of a highly colored green curd was found as a core in the stomach, surrounded by a naturally colored curd, an unexpected result.

A mixture of 1.3 pounds of fine grain and 10 pounds of a 2.5 percent milk was fed to six healthy pigs. Milk was given at the next meal. When killed, 24 hours after the grain mixture had been fed, considerable amounts still remained in the stomach of each pig.

DIGESTION OF THE MILK SERUM

Several tests were made to determine at what rate the milk serum passes through the alimentary canal, as well as the effect of the digestive fluids upon analin colors. Indigo, yellow, red, orange and green soluble colors were used. The colored milks were consumed readily by the pigs at about 6.30 A. M. Slaughter began at about 7.15 and continued until 11 A. M. The alimentary canal of the first pig which had eaten an indigo-colored food was colored to the very extremity of the small intestines. The pigs consuming the milks otherwise colored were killed as rapidly as circumstances permitted, but no appreciable differences in the extent to which the color had penetrated appeared in those killed four hours after its ingestion. Its presence in the arteries and lacteals surrounding the mesenteries could not be detected. Ten tests were made with uniform results. It is evident: first, that these colors are not destroyed by the action of the fluids of the alimentary canal; second, that the milk serum promptly passes from the stomach and travels rapidly until obstructed.

FAT DIGESTION

The fats are acted upon in the small intestines by the enzym steapsin, which splits them into glycerin and their corresponding fatty acids, the former being absorbed. The next step is not understood fully, yet little doubt remains that the free fatty acids, as such, act as an irritant and tend to form sodium or potassium salts. Hence the more fat, the greater the demand for these alkalies. In fact it has been shown by experiment that, "increasing the supply of fat increases the excretion of fixed alkali by the intestines" (14, 21, p. 37).

Both experimental evidence and clinical observation indicate that this acquisition of sodium and potassium is no small factor in the aggravation, if, indeed, it is not one cause, of rickets in bottle-fed babies. It seems that if the quantity of ash in the food is sufficient both to compensate for the loss and to maintain the growth of the bones, no detriment should result, whereas if the amount available for skeletal needs is deficient, bodily welfare is impaired. Furthermore, the affinity of these fatty acids for the fixed alkalies is so great that if the amounts furnished by the food is insufficient, lime may be withdrawn from the bony tissue already formed. It would appear that the result of such continued withdrawal would be malnutrition of the bones and rickets, followed by its long list of superinduced maladies (21, p. 38).

A common effect of high fat feeding is shown in cloyed appetites, under-consumption of food and consequent sluggish peristaltic action, resulting in an accumulation of undigested and, especially, of waste matter in the large intestine. This situation favors the activity of the bacteria of putrefaction and a true decay ensues. The poisons of auto-intoxication are formed and more or less absorbed into the animal system. The symptoms observed at this point are fever, rapid respiration, weak heart action, and, later, occasional convulsions. Unless the fecal matter should break away in diarrhoea, death may follow very suddenly. These symptoms were noted in the trials when milk rich in fat was fed to pigs. Castor oil did not alleviate this condition, but earth proved very effective. Its action is thought to have been largely mechanical, as a stimulus to peristalsis, thereby inducing evacuation.

Touching this matter, Von Noorden (52, vol. 2, p. 212) says in part: "Putrefaction of protein produces ammonia, sulphuretted hydrogen and other gases * * * These are also absorbed by the intestinal wall." "Most of the symptoms which clearly result from the effects of intestinal decomposition are displayed by the nervous system." * * * At one end of the series there is simple headache; at the other, coma, convulsions and collapse" (Ibid., p. 220). "These cases have been regarded by some observers as typical examples of intestinal auto-intoxications" (Ibid., p. 221). "The presence of ptomaines arising in the bowel contents has been pointed out" (Ibid., p. 215). "All these toxic products of the putrefaction of albumen on entering the lymph and blood stream give rise to severe symptoms of cholera infantum" (Ibid., vol. 3, p. 846). Our own observations with baby pigs,

as well as with children fed cows' milk modified to contain a high fat and a low protein and ash contents, are entirely in line with Von Noorden's statements.

DIGESTIVE DISTURBANCES

Throughout the entire series of trials it was noticed that the pigs which received milk testing over four percent fat usually developed some digestive disturbance. As a rule its course ran much as follows:

First: Rapid gain in weight followed by a form of dyspepsia which caused the animals to eat but lightly, to become fretful, to squeal peevishly, and to gnaw the wooden fixtures of their pens to such an extent that splinters of pine wood often were found in their stomachs when they were slaughtered, especially if no soil had been and nose.

Second: This condition was usually followed by constipation. The feces were a dull, slatish-yellow color, round as marbles and almost as hard. If this constipation was allowed to continue, intestinal stoppage ensued, whereupon greater restlessness and peevishness were manifested. If treatment did not bring about relief, either the obstruction gave way and an extreme diarrhoeal condition followed, the stools under these conditions being exceedingly offensive, indicative of putrefaction, or else the pig died in a paroxysm, foaming at the mouth fed.

THE FUNCTION OF SUBSOIL EARTH IN DIGESTION

There is needed in the alimentary canal of every animal some material which shall serve mildly to irritate or to stimulate its muscular activity. Whether this be non-digestible cellulose or plain inorganic matter like earth, seems immaterial. The truth of this well known fact is brought home clearly by the clinical record of some of the experimental pigs as shown on pages 123-135.

The record of No. 32 is quite characteristic of the action of all of the high-fat-fed pigs throughout the entire course of the work, and well illustrates the need of ballast. At the outset it ate liberal quantities of five percent milk and gained weight rapidly for a few days. Soon, however, though consuming no more total solids than did the animals fed milk containing less fat, becoming apparently surfeited, it lost its appetite and became ill. When death seemed imminent, a

quantity of subsoil earth was fed and greedily eaten. The next morning the pen was a stench of putridity, but the pig was alive and hungry, and thereafter so long as it ate skimmilk and earth it thrived.

Certain work reported by Henry (26, p. 98) indicated that the alimentary tract of the pig did not require bulk in order to keep it open and in normal condition. However, it appears from private correspondence that the experimental animal lived entirely upon milk as an organic food from the time she was a small pig until she had grown and herself given birth to a strong litter of pigs, and that she had the "run of a yard" and "free access to an ash heap." In this connection should be remembered Davenport's calf, fed exclusively upon concentrated feeds, which died in paroxysms due to intestinal inaction (26, p. 98).

All the pigs in the trials discussed in this bulletin which received earth regularly throughout the tests remained in good health in so far as their digestive organs were concerned, and it was further noted that at the time of slaughter the residual fecal matter had not decomposed, nor was it really offensive, a condition quite contrary to that invariably observed with those pigs to which earth was not fed.

XIV. HUMAN, COWS' AND SOW'S MILK

CONCERNING HUMAN MILK

It is well known that the milk of a healthy mother is the best food for her infant. Many mothers, however, are unable to nurse their babes and recourse must be had to cows' milk. Now the milk of one species is not necessarily adapted to the nourishment of the young of another species. Great differences in comparative development exist at birth among the several classes of animals. Some develop in a few months, while others, especially the human, live for a time in helpless infancy and require years to reach maturity. The feeling that in the mother's milk nature provides the best food for the young of any species, is unquestionably well founded. But when the human mother is unable to nurse her offspring and a wet nurse cannot be had, the milk of the cow, suitably modified, must be used for nourishment. How shall it be modified? What standard shall be adopted?

The composition of human milk has long been studied, usually, however, in a disconnected sort of way. The results reported by the many analysts differ widely as is shown below; most of these statements representing averages.

TABLE LII—COMPOSITION OF HUMAN MILK

Authority	Ash	Protein	Sugar	Fat
Howell (28)	.20	2.00	5.00	3.10
Abderhalden (1)	Not given	2.01	6.37	3.74
Barthel (5)	.26	1.55	6.44	3.43
Hutchinson (29)	.27	1.62	6.24	3.14
Stohmann (50)	.30	1.72	5.99	2.91
Martin (41)	.20	2.00	5.00	3.10
Schereschewsky (48)	.20	1.50	7.00	4.00
Hall (23)	.40	2.10	6.20	3.80
Jordan (36)	.20	1.42	7.42	2.66
Richmond (47)	.20	1.50	6.80	3.30
“ Maxima	.50	5.56	8.89	9.06
“ Minima	.09	0.85	4.22	0.47

Probably there is a history connected with each of these analyses, but these valuable data are not available.

COMPOSITION AND CLINICAL DATA

The analyses appearing on the next two pages were made at this Station in connection with the study of this problem of infant feeding. The clinical history connected with each sample adds to the value of the tables. The Station is greatly indebted to Dr. C. K. Johnson, Instructor in Pediatrics in the College of Medicine of the University of Vermont, for assistance in procuring these samples.

The data in the two preceding tables indicate that human milk, like cows' milk, varies greatly and in much the same way. The first milk drawn from the breast of the woman or the udder of the cow is usually poor in fat, while the last which is drawn is comparatively rich in fat; but the sugar and protein contents of the foremilk and of the last drafts from the gland are essentially alike. The milk of a nervous woman or of an excitable cow is apt to be small in amount but rich in fat. Temporary excitement and fatigue also tend to increase the fat content. Obvious difficulties exist when one attempts adequately to sample human milk. A cow is milked twice daily and the udder is emptied. The woman nurses her child frequently and the complete emptying of the breast, in the same sense that a cow's udder is emptied, is not easily done. Doubtless many samples of human milk, the analyses of which appear in literature, as a matter of fact were not accurately representative of the entire product of the breast. Clearly no group of figures can be secured which with certainty will represent the "average" composition of woman's milk.

In order to modify cows' milk for the purpose of infant feeding and to obtain uniformity in the product thus modified, some standard

procedure must be used. What should this be? Should the results attained from the analyses of the milk given by sick mothers, or by those who experience difficulty in nursing, or the results attained from inadequate samples, be used in the determination of this standard? Should these milks be included in an "average"? An average analysis is not pertinent, but, rather, a knowledge of what grade of milk best

TABLE LIH—HUMAN MILK, VERMONT DATA

No.	Remarks	Total solids	Ash	Protein	Fat	Milk sugar
1	Mother nervous and excitable.....	Before nursing ... 10.75 After nursing ... 14.69	0.20 0.15	1.78 ...	1.39 5.65	7.38 ...
2	Same source as No. 1, 4 days later	Before nursing ... 11.23 After nursing ... 13.78	0.21 0.16	1.56 1.62	1.84 5.24	7.62 6.76
3	Mother has chronic indigestion	Before nursing ... 9.91 After nursing ... 10.38	0.13 0.15	1.58 ...	1.35 1.89	6.85 ...
4	Same source as No. 3, 4 days later.....	Before nursing ... 10.28 After nursing	0.22 ...	1.75 1.44	0.56 ...	7.75 ...
5	Mother overworked. Got up too soon. Babe six weeks old. Not nursed for five hours previous to taking sample. Full breast.	Before nursing ... 13.32	0.20	1.66	4.86	6.60
6	Russian Jew. Mother 35 years old, fifth child. Babe two months old. Good health. One breast emptied in getting samples.	1st portion 9.98 2nd portion 12.74 3rd portion 13.53 4th portion	0.17 0.19 0.16 ...	0.98 1.07 1.03 1.12	2.23 4.32 6.84 7.92	6.60 7.16 5.50 ...
7	Babe a bouncer; six months old; weighs 20¾ pounds.	Before nursing ... 11.77 After nursing ... ..	... ...	1.45 ...	3.87 6.60	... ...
8	Mother 21 years old; small, frail; weight 110 pounds; good health; second child. Full breast, small feed taken by child.	Before nursing After nursing ... ..	... ...	1.36 1.49	3.60 4.32	... ...
9	Babe six months old; weight 16 pounds; healthy. Intervals between feedings, three hours.	Before nursing After nursing ... ..	... ...	1.28 1.23	5.04 7.92	... ...
10	American; better class. Mother 23 years old; excellent health. Second child. Babe five months old; weight 19 pounds. Fine condition. Voluntarily cut down feedings to 4 in 24 hours. Estimated daily food 40 ounces.	Before nursing After nursing ... ..	... ...	1.11 1.11	1.76 8.21	... ...

agrees with the child and is most likely to produce a strong, vigorous, healthy individual; but not the greatest growth as measured by gain in weight. With this information as a working basis, the writers, as a result of their work and study, find reason to favor the use of a modified milk rather lower in fat and somewhat higher in protein than is usually employed.

TABLE LIII—(Continued)

No.	Remarks	Total solids	Ash	Protein	Fat	Milk sugar
11	Russian Jew; mother 37 years old; third child. Nursed two children one and one-half years each. Babe one month old.	Before nursing ... After nursing ...	... ...	1.61 ...	3.24 5.02	... ...
12	French Canadian. Mother 32 years old. Hard worker, anemic; large milk supply. Babe 11 days old. Good health, feeding irregular.	Before nursing ... After nursing ...	... ...	1.36 1.36	2.88 5.76	... ...
13	Russian Jew, mother's health good. Poor milk supply. Babe ten days old.	Before nursing ... After nursing ...	... ...	1.23 1.63	2.16 2.80	... ...
14	French. Mother 18 years old; health good. Housekeeper, light worker. Large milk supply. Babe 10 days old. Fed every two hours.	Before nursing ... After nursing ...	... ...	1.98 1.93	2.82 5.28	... ...
15	Mother well. Babe well, two weeks old.	Before nursing ...	...	1.63	2.29	...
16	American. First child. Abundant milk supply. Babe well.	Before nursing ... After nursing ...	... ...	1.20 1.27	1.26 3.78	... ...
17	American. Second child. Babe one month old. Vomiting and colic. Nursed frequently and stripped and breast.	Before nursing ... After nursing ...	... ...	1.14 1.19	3.60 5.22	... ...
18	Russian Jew. Child did well until milk supply gave out.	Before nursing ... After nursing ...	... ...	1.05	2.34	...
19	American. First child 4 months old, doing poorly. Vomiting and colic.	Before nursing ... After nursing ...	... ...	...	5.04 3.60	... ...
20	American. Mother overworked. First child, not doing well. Taken off breast when 4 weeks old.	Before nursing ... After nursing ...	... ...	... ...	5.76 7.74	... ...

CONCERNING COWS' MILK

It is well known that cows' milk varies greatly in composition, that breed, period of lactation, bodily condition and many other factors affect it. Dairymen know that either fatigue or excitation tend to increase for the time being the fat content of milk. The relatively quiet Holstein and the relatively placid negress yield milk carrying a moderate fat content, while the nervous Jersey and the excitable woman, over-fed, over-worked or society-worn, yield milk relatively rich in fat. The writers have found a seven percent fat content in a mother's milk when she was tired and nervous, although its normal fat content was only four percent; and the previously healthy babe was quickly out of condition.

The following table, calculated from herd records at this Station, serves to show in a general way the variations in composition between Holstein, Jersey and Ayrshire milks.

TABLE LIV—AVERAGE COMPOSITION OF HOLSTEIN, JERSEY AND AYRSHIRE MILKS

	Total solids	Ash	Protein	Fat	Milk sugar	Nutritive ratio	
Holstein	12.42	0.73	3.13	3.70	4.86	1	: 4.21
Jersey	14.50	0.77	3.76	5.16	4.81	1	: 4.37
Ayrshire	12.71	0.72	3.33	3.84	4.82	1	: 4.04

Differences are recognized other than those in chemical composition between the milk of woman and of the cow. Space does not permit their full discussion. However, mention should be made of the character of their curds when acted upon by pepsin or rennin. Cows' milk coagulates into a firm, rather solid, rubbery, curd mass, while that of the woman forms a flocculent precipitate. It is thought that this physical difference has an important bearing upon the digestibilities of the two milks.

CONCERNING SOW'S MILK

It is far from easy to secure representative samples of a sow's milk. It is doubtless subject to the same fluctuations in quality as are the milks of other mammals. Foremilk and strippings are quite unlike in their fat percentages, though not dissimilar in their solid-not-fat contents. On this account the available data are not large and the results somewhat divergent. The following tabulation sets forth fairly well the chemical composition of this product.

TABLE LV—COMPOSITION OF SOW'S MILK

	Number of analyses	Water %	Dry matter %	Ash %	Casein and albu- min %	Fat %	Milk sugar %	Nu- tritive ratio 1 :
Carlisle (11)	12	80.43	19.57	0.98	6.06	6.89	5.64	3.49
Woll (57)	12	81.49	18.51	0.97	5.75	6.60	5.19	3.49
Dietrich and Koenig (15) ...	7	84.55	15.45	1.10	6.44	4.75	3.16	2.15
Richmond (47).....	..	84.04	15.96	1.05	7.23	4.55	3.13	1.86
Stohmann (50).....	..	85.25	14.75	1.03	8.25	3.16	2.34	1.39
Hall (23) .....	..	....	....	...	6.10	6.40	4.00	3.01

The table exhibits wide variations in fat and milk sugar contents and less marked differences in the protein percentages. This latter figure, however, is consistently high as compared with cows' milk and, consequently, the nutritive ratio of the milk of the sow is narrower than that of the milk of the cow.

It will be remembered that the pigs in the several high-fat trials discussed in this bulletin quite commonly became constipated, or in other ways displayed evidences of malnutrition. The high-fat milks, however, were not high-protein milks. Their nutritive ratios were wide, 1:4.2 or more. It further will be remembered that the pigs thrive when fed milk carrying a 2.5 to 3 percent fat content with nutritive ratios approximately 1:3. The writers feel that the low-fat cows' milk in reality more closely resembles normal sow's milk than does the high-fat product, in that the proportions of protein, fat and milk sugar are more nearly similar. In other words, the similarity of nutritive ratios and not of fat contents seem to govern. The fact that the high fat content of sow's milk is accompanied by a high protein content doubtless is what enables little pigs to thrive on it, whereas they sicken when fed a high-fat, low-protein cows' milk.

XV. SYSTEMS OF INFANT FEEDING

THE AMERICAN OR PERCENTAGE SYSTEM

Infants fed cows' milk often void white, curd-like clots and masses which have been thought to be coagulated but undigested curd or casein. Such children are likely to be somewhat unthrifty and often are subject to colic. The idea that this condition was brought about by inability to digest the casein of cows' milk became a conviction in the minds of many medical practitioners and gave rise to the so-called percentage or "American" system of milk modification.

The "American system," which is quite generally followed in this country, aims to modify cows' milk in order to conform to a standard measured by an assumed composition of human milk. Water then is added in order to reduce its casein content, which naturally decreases the content of the other nutrients as well; cream is added to reestablish the grade of fat assumed to be typical for human milk; and the milk sugar percentage is reinforced by the addition of some form of sugar. Since cane sugar readily ferments, milk sugar has been commonly employed for this purpose, and at present a dextrin-maltose compound is being used somewhat widely.

Since the presence of water retards the coagulation of milk outside the stomach, it is reasonable to suppose that it does so within the stomach. However, the curd mass formed from watered milk is nearly if not quite as firm as that formed from undiluted milk. In order to obviate to some extent the formation of this hard curd, either barley, or oatmeal water is often used to reduce the milk, together with small quantities of lime water which tends to act as a corrective.

THE GERMAN SYSTEM

The German or calorific system of feeding was devised by Heubner, who worked out a ratio between the number of units of energy to be received daily and the weight of the child consuming the milk. His experience, which covered many cases, led him to state that the young child should receive daily not more than 100 Calories of energy per kilogram of body weight during the first three months, usually not more than 90 during the second three months, and 80 or less thereafter, the energy to be derived from milk of a medium fat content.

It is generally believed that the "percentage" system of feeding young infants produces better results than the consumption of undiluted cows' milk; yet overfat and rachitic infants abound, even when thus fed. The German school holds that the vital point in infant nutrition is the energy quotient. The American school stresses the idea that the composition of the milk should be modified to simulate average human milk. The writers hold, however, that neither system is complete; that the ratio of ash to protein and the ratio of ash and protein to the energy consumed should be taken into consideration; that while the production of muscular tissue and fat are important, the building of a strong skeletal structure is also a vital matter. The

importance of the ash content of a ration in bone building has been realized for years; yet many writers on nutrition dispose of the matter with but a casual paragraph, and in the main, until recently, have studied the proteins, fats and carbohydrates. Fortunately fundamental studies dealing with ash metabolism have been multiplied of recent years, culminating in Forbes and Keith's monograph recently issued by the Ohio Station, entitled "A Review of the Literature of Phosphorus Compounds in Animal Metabolism."

SUNDRY OBSERVATIONS

Certain observations made during the trials now under consideration have pertinence at this point. The average initial weight of certain pigs was 22 pounds. At the outset each was fed five pounds of milk daily, standardized to contain 2.75 percent fat, the ratio being ash 1 gram, protein 4.95 grams, energy 77 Calories. While consuming energy daily at the rate of 132 Calories per kilogram weight, the daily gain of the pigs was 0.57 pounds. The quantity of milk fed was increased in proportion to the gain in weight, yet the ratio of the constituents was held constant. The feed was continued for 50 days. Experience gained in earlier trials led the writers to conclude that these pigs would have made more gain on milk containing a slightly higher percentage of fat—say 3 percent—having a ratio 1:5:85.

The chemical and clinical data afforded by these trials indicate that when the milk contained a fat percentage small enough to afford a nutritive ratio 1:3 or more, yielding a "ratio of essential ingredients" of about ash 1 gram to protein 5 grams to energy 85 Calories, and when the amount fed daily furnished from 125 to 130 Calories per kilogram weight, the pigs made excellent gains and were healthy. On the other hand, when the fat content was increased until the nutritive ratio equalled 1:4 or more and the "ratio of essential ingredients" was ash 1: protein 5: Calories 115, and energy was consumed at the rate of only 100 Calories per kilogram, the pigs lost appetite, developed a dyspeptic hunger, refused food and lost weight. On a consumption of 100 Calories per kilogram, they lost weight, yet they refused to eat more. When they were given a milk carrying only 2.5 to 3 percent fat and a nutritive ratio 1:3, their appetites returned, they consumed a large quantity of milk, thus receiving the needed energy, and they promptly gained in weight and vigor.

A study of sow's milk (pages 105-106) shows that while its ash and protein percentages are high when compared with cows' or human

milk, the nutritive ratio ranges from 1 : 2 to 1 : 3.5 which is much lower than that of cows' milk. The exact ratio for best growth will vary somewhat with the normal rate of growth of the animal under consideration; but if cognizance of this matter must be taken in connection with the feeling of one species of animal, it is very likely that it must be taken into account in feeding another species. The writers do not claim that a ratio best suited to the needs of the pig of necessity will be best suited to the needs of every human infant; but it is unquestionably true that for each infant some ratio is the right ratio and that in the interest of its well being it should be determined and followed as closely as individual peculiarities will permit.

It is the common experience of western stock growers in making beef or pork that they must first produce the frame work and muscular tissue and, later, the fat. They have learned that constitutional weakness and poor growth are induced if young animals are fed highly fattening foods. Their findings are applicable to the nutrition of the human infant.

Is the milk of one cow or is herd milk preferred in infant feeding? Some dietitians hold that the milk of pregnant cows or of cows at the period of oestrus (heat) possesses characteristics which make it more or less unfit for infant feeding. Some purveyors of "baby milk" have gone so far as to spay the cows used in its production, with a view of overcoming the supposed difficulty and of securing a more uniform product. In the course of the feeding trials now under consideration leucocyte counts were made on some 50 milkings, but no relationship could be established between the count and either oestrus or pregnancy.

It was thought that possibly the rate or, rather, the rapidity of the coagulation of milk by rennet might afford some clue to the relative merits of sundry milks. To test the matter one of us (R. M. W.) made several hundred coagulation determinations in order to ascertain the effect of oestrus, period of lactation, general health of the cow, etc., upon the rate of coagulation; but no connection could be established between either oestrus or pregnancy and the rapidity of coagulation (53, pp. 120-121). Normal milk coagulates under test conditions in about 18 minutes. Some milks from cows far along in lactation and on the point of drying off did not coagulate until three hours had elapsed. The milk from one cow, which for some reason temporarily gave bloody milk, did not coagulate at all, although the test was continued for 24 hours. Clearly such abnormal milks could not digest

properly if fed to an infant and would in all probability injuriously affect its health.

Since the effect of such differences would be minimized by dilution, it would seem that on this account at least mixed herd milk would be more desirable than the milk from an individual animal for infant feeding.

A COMBINED SYSTEM

There is nothing, however, really incompatible between the American and German systems of infant feeding. Each possesses merit. It seems to the writers the part of wisdom to make a selective combination. To this end the writers suggest such a combined system, one which retains the percentage statement of the one and the Calorie dictums of the other, one which lowers the high fat percentage usually prescribed by the American system, thereby diminishing the ratio between the protein, carbohydrates and fat, and specifies that from one-third to one-fourth of the Calories fed be derived from protein, one-third from fat and the remainder from milk sugar and dextrin-maltose. It appears to the writers that the tendency when using either system seems to be in the direction of an excessive use of fat, since this nutrient may be easily regulated to obtain any desired number of Calories. However, the protein and sugar contents should be proportionally raised so that the nutritive ratio will not be too largely augmented. Many infant troubles of a digestive nature result from overfeeding early in life, and the fat is most apt to be the disturbing factor.

No hard and fast rule can be formulated applicable to all cases of infant nutrition. The writers suggest in lieu thereof a milk standard which it is believed should serve as a satisfactory base ration, one which, with simple dilution with water or gruel and the addition of milk sugar or dextrin-maltose, will furnish proper nourishment for the normal human infant. They feel that if directions are followed it will be impossible greatly to overfeed with fat, and that, as a result, the evils attendant upon the overconsumption of fat, e. g., dyspeptic hunger, colic, constipation and eczema, will be minimized. They are convinced that protein is rarely the disturbing nutrient and believe that no rational grounds exist for the general practise of feeding a human infant a diet low in mineral matter and protein and excessively rich in sugar and fat.

Of course under normal conditions artificial feeding should never replace breast feeding. Whenever possible the latter should be en-

couraged. It is better to supplement a scanty breast milk supply by small artificial feedings than to discard it entirely.

Johnson (34) states that it may often be well to resort to "complemental feeding," the substitution of one or more feedings of a modified milk for a corresponding number of breast feedings, as suggested by Southworth (52); or to attempt "supplemental feeding, putting the infant to the breast for a certain period, after which the infant is given a bottle of modified milk and allowed to nurse until satisfied."

It seems inadvisable to attempt to feed the Calorie requirement of the German standard during the first few weeks after birth, but rather to encourage a gradual tolerance for artificial food, thus inducing relative moderate initial gains, ultimately reaching the requirement of 40 Calories per pound of weight. The German system aids one in determining whether or not an infant is being overfed. It is then pertinent to discover whether the digestive disturbances are due to the fat or the sugar contents of the ration. Poor tolerance for milk sugar is indicated by thin, watery stools while excessive fat consumption is manifested in either a soapy or a hard, dry stool.

Directions for infant feeding to be practical must be simply stated and the routine of food preparation must be such that the mother or nurse can follow it with exactness and dispatch. With these limitations in view the writers suggest the following procedure.

In order to produce a milk food likely to be adapted to the uses of the normal human infant, the quart bottle of approximately 4 percent milk, such as is generally obtainable from the local milk dealer, is selected.¹ It should stand from 3 to 4 hours or more in order to allow the cream to rise. Under usual conditions this occasions no delay since milk from the previous night's supply is already in suitable condition and the morning's milk will have been bottled an hour or two before delivery.

The top two ounces are removed, using a suitable spoon or dipper, and the remaining 30 ounces mixed by pouring from one bottle to another. The milk would then contain approximately: Water 88.4 percent, ash 0.7 percent, protein 3.7 percent, milk sugar 4.7 percent, fat 2.5 percent. Its nutritive ratio will be about 1 : 2.8 and it will contain 18

¹It is, of course, presupposed that, as far as may be, due care is exercised to insure the healthfulness and cleanliness of the supply.

Calories per ounce, approximately 4.6 of which are derived from the protein, 6 from the milk sugar and 7.4 from fat.¹

The milk is now ready for dilution with water—preferably boiled—or gruel, and for an addition of either dextrin-maltose or milk sugar in quantity enough to make the sugar content of the diluted mixture approximately 6 percent.

In the statement of general directions which follow, the writers have drawn freely upon material in the many volumes published on infant feeding, especially Grulee (21), and have simply recommended the special standard milk just described.

FACTORS TO BE CONSIDERED IN INFANT FEEDING

A general rule governing the amount to be offered at each feeding may be stated as follows: Offer the child as many ounces as he is months old plus one to one and a half.

In the first place it should be clearly understood that the first three months of a child's life is a critical period. A large gain in weight is neither important nor desirable. One should seek rather to avoid nutritional disturbances and to maintain health and vigor. Water, and that only, should be given the first day or two after birth, at intervals of from three to four hours and in two-ounce portions. This may be followed with three-ounce feedings of a milk and water mixture, equal parts of each. Later, up to two months and over, the amounts of this food offered at each feeding may be gradually increased until four to five ounces are fed; and these may be fortified by adding either dextrin-maltose or milk sugar in the proportion of one to two level tablespoonfuls to the entire daily mixture.

After the child reaches the age of three months, a milk modified according to the formula above indicated may prove serviceable in the feeding of a normal infant as set forth in the following statements. Obviously the *age and weight* of the child are factors to be considered in determining the amounts to be fed. The capacity of its stomach, the number of daily feedings and the intervals between them are in the main dependent upon its age; and the amount of nutrients needed

¹The Calories per ounce may be readily calculated with approximate accuracy using any milk analysis, as follows:

Calories per ounce = [(Fat $\times$ 2½) + protein + milk sugar] $\times$ 1¼.

Thus in the case above cited:

(2.5 $\times$ 2½ = 5.63) + 3.7 + 4.71 = 14.03.
14.03 $\times$ 1¼ = 17.5.

It should be noted that each percent of fat in milk is equivalent to approximately 3 Calories per ounce; each percent of protein or milk-sugar, to approximately 1½ Calories per ounce; and one ounce or three tablespoonfuls of dextrin-maltose or milk sugar, to approximately 120 Calories.

for maintenance and growth are similarly dependent upon its weight. The following table indicates some of these items.

Age	Capacity of stomach	Suggested feedings	Interval between feedings
At birth	1½ to 2 ounces	8 per day	3 hours
Three months	4½ ounces	5 to 6 per day	4 hours
Six months	6 ounces	5 per day	4 hours
Eight months	7 ounces	5 per day	4 hours
Ten months	8 ounces	4 per day	4 hours
Twelve months	9 ounces	4 per day	4 hours

A. The ounces of food offered daily will equal the stomach capacity multiplied by the number of daily feedings.

B. The child's weight in pounds multiplied by one and a half equals the number of ounces of milk which should furnish enough protein for maintenance and growth.

C. Subtracting the result of the second multiplication (B) from that of the first (A) gives the ounces of water needed to dilute the milk for a day's feeding.

$$A - B = C.$$

The daily ration thus made may be fortified by the addition of three level tablespoonfuls either of dextrin-maltose or milk sugar. When the child is old enough to utilize undiluted milk, one tablespoonful or less of dextrin-maltose or milk sugar will suffice.

An example may serve to make this procedure more clear.

Child 3 months old, weight 12 pounds. Stomach capacity 4.5 ounces, 6 daily feedings.

$$4\frac{1}{2} \times 6 = 27 \text{ ounces A}$$

$$12 \times 1\frac{1}{2} = 18 \text{ ounces B}$$

$$\text{Water} = 9 \text{ ounces}$$

Use 18 ounces of milk from the 30 ounces left in a quart bottle after the two top ounces of cream have been removed; add 9 ounces of water and from 2½ to 3 level tablespoonfuls either of dextrin-maltose or milk sugar and mix thoroughly.

It is, of course, understood that no single milk formula is universally applicable; that every little infant stomach is a private experiment station; that the system above outlined is suggestive only. There is this much to be said about it, however, that it has been used in actual pediatric practice with excellent results.

It is important that one distinguish clearly between the immediate effect of a food as shown by the readiness and completeness of its digestion, which is often determined by the individuality of the child, and the more permanent effect as shown by the character of the tissue

which is formed. A food must "agree with" a child; yet a food which may agree—that is to say may digest without immediate ill-effect—may be of such a character as in time to produce abnormal growth. Clearly it is an important matter that the food shall not only agree temporarily, and of course ultimately, but that its chemical composition shall be such that its nutrients exist in the right proportion to build sound and healthy tissue. The former condition depends but little upon the composition of the food, the latter is greatly concerned with it.

A food may not agree with a child for the time being, may indeed act almost as does a poison, yet if its use is discontinued for a time and then gradually and carefully reestablished, a tolerance may be developed which will allow it to be continually and satisfactorily fed. Whether a child can or cannot tolerate a food is due primarily to its individuality, but the character of the body gain resulting from the consumption of a given food depends upon the food itself.

The thinner milks more economical. Although the rearing of infants at low cost should not be and is not a matter of first importance, yet it is a matter which is worthy of serious consideration. Recent studies have shown that the less expensive milk foods containing a reduced fat percentage have produced stronger and more healthy children than have more costly rations. Butter fat in the form of cream is worth at different seasons of the year from 30 to about 50 cents a pound. If a 4 percent milk is bought for 8 cents per quart, its non-fatty constituents, which produce the stronger infant, are costing not more than 25 cents per pound, or one-half the higher price paid for fat. Clearly a reduction in the fat percentage of the milk fed the child is in the direction of true economy.

It has been shown by Osborne and Mendel (43-45) and by the Misses Wheeler and Beister (55), that milk not only furnishes highly valuable food, but that also it favorably influences the digestibility of the other foods consumed along with it. For this reason, among others, children under five years of age ordinarily should be encouraged to consume moderate quantities of milk provided it has been made and kept in a cleanly way. During this period especially, a milk of medium or low fat content but rich in ash and protein is to be preferred. Plain skimmilk might best suit the needs of hearty eaters showing a tendency toward overfatness, while perhaps a richer milk might be fed to the child which has passed infancy and requires additional energy.

XVI. OVERFEEDING

It is stated elsewhere (pages 107-110) that certain systems of infant feeding which have enjoyed wide vogue employ relatively high fat formulas. There seems reason to believe that many infants are over-closed with fat, that many of them eat too much, that fat cheeks are not of necessity an evidence of bodily health.

An animal's appetite is not always a trustworthy index to the quantity of food it needs. In the trials now being reviewed, many, indeed most, of the little pigs were willing to consume and some did consume more food than they were able to assimilate and build into body tissue. This point was clearly brought out in the record of three of the six pigs used in "standard" establishment (pages 26-31). In these instances an increase over and above a sufficiency of 0.2 pound of the grain mixture each morning and evening, although readily consumed, resulted in a reduction in the rate of body gain. In other words, they gained less rapidly and at greater food cost when overfed. Cows have been known to increase their milk flow immediately following a two pound reduction in their daily hay ration. Unquestionably they were being burdened by the excess of food.

Bearing in mind these facts brought out by animal experimentation, the writers have closely observed the eating habits of young children. They are convinced that many are permitted, indeed encouraged, to eat more than they can properly utilize and this, too, whether breast-fed or artificially nourished. Such children would be more healthy, less peevish, better able to resist infection, if they ate less.

It were better in warm weather slightly to under-feed than to over-feed. Indeed Johnson (34) states that "much of the bowel disturbance during the dreaded second summer (is) due to over-feeding."

The high fat theory of milk modification is found throughout American pediatric and dietetic literature. Its justification appears to rest upon the supposition that human milk contains a considerable amount of fat. However, an incorrect standard is often adopted, a standard which carries too much fat in proportion to protein. Although many samples of woman's milk given by sick, nervous or over-fed mothers, contain from 3.5 percent to 4.5 percent fat or even more, it does not follow that a high fat content is best for the growing child, nor that the milk of mothers who are rearing strong babes will show so high a fat content. The colored women of the South as a rule are good wet nurses. From private communication to one of us it appears that extended examination has shown that the fat content in the milk of these vigorous colored women is low, varying of course but averaging hardly three percent. It is also known that the first milk

drawn from the breast carries far less fat than does the later portion. (see table LIII, sample 6, p. 103) a difference particularly marked in the case of women with full breasts. With such a nurse the child does not draw all the milk at any one feeding and, therefore, secures milk containing a lower fat content than the average for that particular woman. Children reared at such a breast do well if not allowed to consume too much. When, however, the fat content of a substitute for mother's milk is rather high and little or no check is made on the amount consumed, there is great danger of overfeeding.

Brennermann (8, p. 1344) concludes an article on "Nutritional Disturbances in Infancy Due to Overfeeding," thus:

1. Overfeeding is so prevalent in this country that it is the rule.
2. Overfeeding is second to no other factor in the pathogenesis of infant feeding.
3. Overfeeding presents an easily recognizable, definite symptom complex.
4. The percentage method is inadequate to prevent overfeeding. as mere percentage leaves undetermined the amount of food the baby receives.
5. To feed rationally it is necessary to know how much food the baby is getting in proportion to its weight. This is best expressed in terms of energy quotient.
6. The disturbing element in overfeeding with cows' milk is the fat.
7. Fat in excessive amount, but not protein, regularly produces constipation.
8. It is unnecessary to give more fat than protein in cows' milk."

According to Budin a child that must be artificially reared should be fed undiluted cows' milk of low fat content, 2.5 to 3 percent at the outset, modifying this later if found to be necessary. He says that "our infants on mixed and artificial feeding are never affected with eczema, for they are not overfed, they are free from digestive troubles" (9, p. 146). "When mothers will lead well-regulated lives as regards food and exercise and infants cease to be overfed, eczema will be eliminated from the affliction of nurslings" (9, p. 93).

The evidences of overfeeding are: a too rapid gain in weight followed by irritability, restlessness and broken sleep followed by constipation. The feces, heretofore of normal odor and color, are apt to become pale gray, hard and dry, while their odor is strong and suggestive of decomposition. Grulee (21) states that polyuria, sweating about the head and rapid respiration are also indicative of over-feed-

ing; and Johnson (34) says that skin eruptions as eczema and boils are apt to occur. Furthermore Johnson (32) stresses the advisability of carefully examining the infant's stools, in order to secure evidence as to completeness of digestion. He goes so far as to say that he "would much prefer to see the stool than the infant if both could not be seen."

It is not improbable that to overfeeding with rich milk rather than to an undesirable bacterial content may be attributed the pathogenic condition which has given rise to statements to the effect that "certified milk usually induces constipation and the stools are hard and light" (51) and that "it is a well known clinical observation that most infants are constipated on cow's milk that is not decomposed by bacteria" (58).

Obsessed by the theory that the casein of cows' milk is digested with difficulty, Lowenburg (39) recommends fat 4, protein 2, sugar 7, neglecting the ash. Lackner (38) says that "this doctrine (that cows' milk casein is hard to digest) has been disproved by experiments on infants. In fact, it was proved that the nitrogenous compounds, (including) those of cows' milk, as well, were easily and thoroughly digested (about 5.5 percent loss), and when not made use of in the body were chemically changed and passed in the urine." Jacobi in the same journal (30) says that "the advice to add cow's milk fat to cow's milk in order to make it more nutritious or to make its casein more digestible, is dangerous. * * * The danger of overfeeding with fat can be obviated by reducing its percentage in milk mixtures to 2 or 2.5 percent." Hall (23) says that "the fat is the chief disturbing element in feeding cow's milk. * * * The fat which milk contains also seems to exert a restraining influence on the amount of gastric juice secreted. It may be for this reason that skimmilk is more easily digested. Buttermilk is the most digestible form." And Hutchinson remarks that "it (buttermilk) is very easily digested, owing to the absence of fat and to the fact that its casein is present in a finely flocculent form" (29, p. 138). Fischer says that "according to Finklestein and Meyer, casein can be fed to very sick infants and will be assimilated in small or in large doses. * * * Casein is indicated to combat diarrhoea. * * * This teaching based on experimental feeding reverses our former theories concerning the dangers of giving large percentages of protein. * * * It (casein) has been successfully used by me in cases of intestinal disturbances, enteritis (dyspepsia), atrophy (decomposition), and cholera infantum (intoxication)." * * * "My experience with topmilk feeding has been bad," (18, p. 138).

In the face of such evidence it seems inconsistent to load such a food with fat on the theory that the child requires it, when infants are

being successfully reared on buttermilk containing practically no fat. Evidently then, fat *per se* (45) is not essential to the life or growth of the child, and an excess of fat is a detriment since it causes diarrhoea, constipation and all their consequent ills as well as aggravating rachitic conditions. In view of the fact that our own experimental findings covering a period of several years and including as subjects 162 baby pigs, clearly show that rich milk is not tolerated by pigs as well as is milk containing a smaller quantity of fat, we are inclined to hold with Czerny and Steinitz (14), Brennemann (8), Jacobi (30, 31), Budin (9), and others that a high-fat percentage of milk for infants is not necessary but, rather, is harmful, and that in most instances it should be suitably proportioned to the ash, protein and milk sugar contents.

In a large children's hospital visited by one of the writers the old "top milk formula"—8 of the 16 ounces of top milk, 20 ounces of boiled water, 1.5 ounces of milk sugar, and a trace of salt—was being employed as long as the infants could tolerate it. This mixture contained about 0.2 percent ash, 1.1 percent protein, 6.7 percent milk sugar and 2.1 percent fat, with a nutritive ratio of about 1:11, and approximately 16 Calories per ounce. Eczema was said to be very prevalent. To such cases was fed a buttermilk mixture low in fat, with a nutritive ratio of about 1:2 and carrying 10 Calories per ounce. This was fed alternately with the top milk mixture, three feedings of each in the 24 hours for young infants. When fed in equal quantities, these two would furnish the child a food having a nutritive ratio of about 1:4.3. It is well understood that sudden and violent changes in feeding should be avoided, whether young or mature animals, human or brute, are concerned; yet in this instance a sweet, high-fat food was displaced by a sour, low-fat food, or the reverse, six times a day, 42 times each week. The question naturally arises why would it not have been advisable to have placed the infants from the outset upon a food carrying less fat and more protein, in order to develop strong tissue, to prevent eczema and fatty constipation and at the same time to avoid violent changes in diet. In other infant hospitals visited, the "top milk system" has been discarded and whole milk used in its place. The writers believe that whole milk will furnish a more nearly balanced ration than will top milk, provided its carbohydrate content is not too great, and that it should carry not more than four percent and preferably not over three percent of fat.

Several specialists in infant feeding now employ a more rational system than the top-milk, high-fat one, a system much like that suggested on pages 111-113. It is believed that the practice is extending

XVII. REFERENCES

The long delay experienced in issuing this bulletin and the difficulties incident to working at arms' length have conspired to render the following list of references very unsatisfactory. It is in no sense a complete bibliography; and it contains almost no references to literature within the last three years. Although issued in 1916 this bulletin is really of the vintage of 1913.

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XVIII. APPENDIX

1. CLINICAL RECORD OF ANIMALS CONSIDERED INDIVIDUALLY BY NUMBER

RECORD OF TRIALS WITH CALVES (BEACH)

1907. PRELIMINARY WORK

Durtje's calf: Holstein: fed for 30 days in mid-summer on Holstein milk from dam, analyzing approximately 12.2 percent total solids and 3.3 percent fat; 6 days old at outset; made good gain (62 pounds), which shows calf was in good condition; nutrients fed carefully accounted for; chemical composition of animal not determined.

Rosel's calf: grade Jersey: fed for 30 days in mid-summer on Holstein milk, analyzing approximately 11.7 percent total solids and 3 percent fat: 7 days old at outset; made good growth (58.5 pounds); nutrients fed carefully accounted for; composition of animal not determined; must have been in healthy condition to have made the growth indicated; chemical composition of animal not determined.

1907. RUN I. (1-6) (BEACH)

Object: Comparison of Holstein and Jersey skimmilks, and relatively low-fat and high-fat milks.

1. Jane's calf: grade Jersey: fed for 29 days in late summer on Holstein skimmilk, carrying approximately 8.7 percent total solids: 13 days old at outset; made moderate gain (41 pounds), and by butcher was adjudged "poor veal," worth 4 cents live weight; but little fat on carcass.

2. Mona's calf: grade Jersey: fed for 29 days in late summer on Holstein milk, analyzing approximately 11 percent total solids and 2.5 percent fat: 11 days old at outset; fair gain (41 pounds); butcher judged it "fair veal," worth 5 cents live weight; fair amount of fat on carcass.

3. Sabra's calf: grade Jersey: fed for 29 days in late summer on Holstein milk, analyzing approximately 13 percent total solids and 4.4 percent fat: 6 days old at outset; made good gain for weight at start (49 pounds); carried more fat than above named animals; judged by butcher to be "good veal," worth 6 cents live weight.

4. Angle's calf: grade Jersey: fed for 30 days in late summer on Jersey skimmilk carrying approximately 9.6 percent total solids: 15 days old at outset; made poor gain (38 pounds); intestinal malformation; slaughtered when in ill health; butcher judged it "poor veal," worth 3 cents live weight, and 6 cents dressed; practically no fat on carcass.

5. Ardelle's calf: grade Jersey: fed for 30 days in late summer on Jersey milk, analyzing approximately 12.6 percent total solids and 3.2 percent fat: 12 days old at outset; made fair gain (41.5 pounds); called "good veal," worth 5 cents live weight and 8 cents dressed; fair amount of fat on carcass.

6. Peggy's calf: grade Jersey: fed for 30 days in late summer on Jersey milk, analyzing approximately 14.5 percent total solids and 5.3 percent fat: 9 days old at outset; good gain (49.5 pounds); considerable fat on carcass; produced "good veal," worth 6 cents live weight and 9.5 cents dressed.

RECORD OF TRIALS WITH PIGS

1907. RUN A (1, 2, 7-12) (BEACH)

Bought of F. A. Cassidy, Enosburg Falls; farrowed August 4; received in fair condition Sept. 13; not weaned; sire an O. I. C. boar; dam "nearly thoroughbred"; fed 39 days; slaughtered October 22.

Object: Comparison of Holstein and Jersey skimmilks and relatively low-fat and high-fat milks.

1, 2. Check pigs. (Nos. 3 to 6 non-existent).

7. Fed Holstein skimmilk, containing approximately 9.1 percent total solids.

8. Fed Holstein milk, containing approximately 11.3 percent total solids and 2.4 percent fat.

9. Fed Holstein milk, containing approximately 13.4 percent total solids and 4.6 percent fat.

10. Fed Jersey skimmilk, containing approximately 9.6 percent total solids.

11. Fed Jersey milk, containing approximately 12.3 percent total solids and 2.9 percent fat.

12. Fed Jersey milk, containing approximately 13.8 percent total solids and 4.6 percent fat.

No post mortem or other clinical data available. It is evident, however, that digestive disturbances occurred, since castor oil, earth, etc., were used.

1908. RUN B (13-26) (BEACH)

Bought through Hon. G. S. Fassett of Enosburg; from two litters, one of 6 "black" pigs, the other "5 spotted and 3 white"; received in fair condition April 29, 30, and held on skimmilk until May 2, when experimental feeding began; fed from 30 to 94 days.

Object: Same as run A.

13. Fed Holstein milk, carrying approximately 11.9 percent total solids and 3.2 percent fat; held 31 days until it had doubled its initial weight, when it was slaughtered; apparently a normal, healthy growth was made.

14. Fed Holstein milk, carrying approximately 14.5 percent total solids and 5.9 percent fat; increased in weight from 17.9 to 32.5 pounds in 4 weeks; sickened, refused food, lost weight and died June 9 after 39 days feeding; post mortem revealed little blood, liver white, spotted, jejunum ulcerated with membranous deposits; no appearance of swine plague; no ulceration in cecum or colon.

15. Fed Holstein milk, carrying approximately 11.8 percent total solids and 3 percent fat; increased in weight from 15.4 to 28.8 pounds in 6 weeks, but weighed 2 pounds less at the end of the following week, and died June 27 after 57 days feeding; post mortem showed no unusual or abnormal condition.

16. Fed Holstein skimmilk, carrying approximately 8.8 percent total solids; increased in weight from 19.9 to 28.5 pounds in 4 weeks; somewhat constipated; slaughtered on June 2; in normal condition; large lump of curd in stomach.

17 and 25. Check pigs.

18. Fed Holstein skimmilk, carrying approximately 8.9 percent total solids; increased in weight from 21.7 to 58 pounds in 94 days; long life and good growth, with absence of comments indicate health.

19. Fed Jersey milk carrying approximately 12.8 percent total solids and 3.2 percent fat; slaughtered June 2, having increased in weight from 15.9 to 27.5 pounds; liver apparently somewhat out of order, but otherwise in prime condition.

20. Fed Jersey skimmilk, carrying approximately 9.5 percent total solids; increased in weight from 16.7 to 64.5 pounds in 94 days; long life, good growth and absence of comments indicate health.

21. Fed Jersey milk, carrying approximately 14.9 percent total solids and 5.4 percent fat; increased in weight in 31 days from 14.7 pounds to 21.6 pounds; liver light colored, friable, brittle; in highly constipated condition, with large lump of undigested curd in stomach and with small intestines full.

22. Fed Holstein milk, carrying approximately 14.4 percent total solids and 5.8 percent fat; increased in weight from 16.2 to 24 pounds in 31 days; liver very light colored, friable and brittle; mesenteric glands enlarged and soft; intestines contained substance resembling undigested fat; small intestine full and enlarged; stomach nearly empty.

23. Fed Jersey skimmilk carrying approximately 9.6 percent total solids; slaughtered in 31 days, having increased in weight from 17.3 to 29.6 pounds; post mortem notes indicate constipation; otherwise in prime condition.

24. Fed Jersey milk carrying approximately 12.2 percent total solids and 2.8 percent fat; increased in weight from 15.3 to 66.5 pounds in 94 days. notes indicate that it required earth occasionally; good growth and absence of other comments indicate health.

26. Fed Jersey milk carrying approximately 15 percent total solids and 5.6 percent fat; increased in weight from 15 to 24.4 pounds in 4 weeks, then lost weight for 2 weeks; became diarrhoeal and very weak and was killed June 15 after 45 days feeding; post mortem shows no visible derangement, which is evidence that the trouble was due to digestive difficulties.

27. Non-existent.

1908. RUN C. (28-41) (WASHBURN)

Bought through Hon. G. S. Fassett of Enosburg; two lots of 7 each; received August 19 and 21; first lot (28-33, 40) through error of a farm hand was overfed on arrival with sour milk, causing diarrhoea; not started on experiment until cured, August 27; second lot (34-39, 41) started August 22; first lot fed 35 days, second lot 48 days.

Object: Same as run A. Procedure essentially similar to that of run A, except that half of the pigs received lime water.

40 and 41. Check pigs (one from each litter).

28. Fed Holstein skimmilk carrying approximately 8.8 percent total solids; increased in weight from 11.8 to 25 pounds in 35 days; slaughtered September 26th; vigorous, sound throughout.

29. Fed Holstein skimmilk carrying approximately 8.7 percent total solids plus lime water; increased in weight from 9.3 to 14.5 pounds in 35 days; slaughtered September 26; weak and sick at the time; lungs in bad condition, many lobes seeming never to have been filled with air, impossible to inflate on vigorous trial; cannot be deemed to be a normal animal, yet no evidence exists that bad condition was due to nature of ration.

30. Fed Holstein milk carrying approximately 14.5 percent total solids and 5.9 percent fat; increased in weight from 16 to 29.6 pounds in 35 days; slaughtered September 26; sound at post mortem, though had suffered from diarrhoea and had been fed earth several times during the earlier weeks.

31. Fed Holstein milk carrying approximately 11.7 percent total solids and 3 percent fat; increased in weight from 15.3 to 30.8 pounds in 35 days; slaughtered September 26; one lobe of the lungs would not inflate, the inactive portion being dark colored and nearly solid with water and blood; though far from being perfect, made normal growth.

32. Fed Holstein milk carrying approximately 14.5 percent total solids and 5.9 percent fat plus lime water; was sick at the outset; recovered; suffered relapse, diarrhoeal; was fed earth on September 2, which appeared in feces the next morning; immediate recovery; fair gains during the fifth and last week; killed September 26; several lobes of the lungs attached one to another by strong filaments and the lungs attached to the body wall by muscular strings; station veterinarian diagnosed pneumonia; animal not sufficiently representative to warrant attributing condition to its ration.

33. Fed Holstein milk carrying approximately 11.7 percent total solids and 3 percent fat plus lime water; was in especially bad condition at the outset; diarrhoeal; passed mucus; was fed earth September 2; improved; 2.7 percent milk replaced with skimmilk and earth September 4; continued improvement, but not entire recovery; formalin, added to the skimmilk September 6 and 7, seemed serviceable and animal improved; in good condition September 10; slaughtered September 26; lungs in bad condition, several pustules of yellow-green, cheesy pus occurring in the tissue; station veterinarian diagnosed pneumonia; ration should not be held accountable for this condition.

34. Fed Jersey skimmilk carrying approximately 9.6 percent total solids plus lime water; healthy at outset and remained so; increased in weight from 18 to 54 pounds in 48 days; slaughtered October 14; pronounced sound.

35. Fed Jersey milk carrying approximately 14.6 percent total solids and 5.3 percent fat; healthy and apparently sound at the outset; made excellent gains for 35 days, from 19 to 41.6 pounds; was in fine condition so far as form was concerned, except that it was too fat. On September 25, attendant, while cleaning the pen leaned the feeding rack, which was made of boards and weighed from 12 to 15 pounds, against the side of the pen. The pig knocked it over, and as it fell he jumped away but was struck by the corner

of the rack; whereupon he laid down, grunted and died. The carcass was handled as usual that day. Diligent search was made for the place of injury, but none could be discovered. Death was undoubtedly caused by this slight shock to an animal of exceedingly low vitality.

36. Fed Jersey milk carrying approximately 14.6 percent total solids and 5.3 percent fat plus lime water; in good condition at the outset; made rapid gains at first, but slower thereafter; from 17.5 to 48.5 pounds; was to have been slaughtered on October 14, after 48 days feeding, but died of fright en-route from pig house to laboratory, its vitality being too low to withstand the shock and excitement of being carefully placed in a box and drawn 40 rods; carcass was immediately handled and bled well, so that the chemical data were not vitiated.

37. Fed Jersey skimmilk carrying approximately 9.5 percent total solids; in good condition at the outset and remained so throughout; increased in weight from 14.8 to 45 pounds in 48 days; slaughtered October 14; pronounced sound.

38. Fed Jersey milk carrying approximately 12.2 percent total solids and 2.8 percent fat plus lime water; in good condition at the outset; was off feed for a day or two about the middle of test; increased in weight from 19.8 to 51.8 pounds in 48 days; slaughtered October 14; pronounced sound.

39. Fed Jersey milk carrying approximately 12.2 percent total solids and 2.8 percent fat; in good condition at the outset; increased in weight from 19.8 to 56.8 pounds in 48 days; the only pig of the 162 known to vomit, an episode which was followed by a run of diarrhoea for a day; promptly recovered following feeding of earth; killed October 14; thoracic cavity contained considerable water; otherwise in sound condition.

1909. RUN D (42-55) (WASHBURN)

Pure-bred Chester-Whites from Heart's Delight Farm (W. H. Miner), Chazy, N. Y. All sired by same boar; 42 and 53 farrowed April 7, 43-48, April 12, 49-55, April 9; received in excellent condition; fed for 39 days from May 16, save 44 and 49 (died); slaughtered June 24.

Object: Same as Run A. Procedure essentially similar to that of Run A, except that to the ration of half the pigs, earth was added with a view of lessening intestinal stagnation.

42. Fed Holstein milk carrying approximately 13.5 percent total solids and 5 percent fat without earth; increased in weight from 23.7 to 56 pounds; sound but of low vitality.

43. Fed Holstein milk carrying approximately 13.5 percent total solids and 5 percent fat with earth; increased in weight from 18.9 to 41.8 pounds; in good health throughout; excellent condition.

44. Fed Holstein milk carrying approximately 1.12 percent total solids and 2.6 percent fat without earth; increased in weight from 17 to 27.3 pounds in 3 weeks; in good condition at outset and did well for a while, fell ill, recovered for a while, then lost weight and died June 20, apparently because of poisoning of the system brought about by putrefaction of the intestinal contents, which in turn had been augmented by intestinal stoppage due to the formation of hard lumps resembling balls of sawdust, which were not such, however, but fecal matter undischarged owing to intestinal stagnation.

45. Fed Holstein milk carrying approximately 11.2 percent total solids and 2.6 percent fat with earth; increased in weight from 18.3 to 43.3 pounds; ill for a day, June 15; in normal condition when slaughtered.

46. Fed Holstein skimmilk carrying approximately 8.8 percent total solids without earth; increased in weight from 13.3 to 24.2 pounds; small pig from the outset; placed on skimmilk because previous experience indicated that he could not stand a richer diet; kept alive until slaughter day by dint of much effort on the part of the attendant and the use of castor oil to secure evacuations; carcass contained practically no fat, which may in part be due to illness, in part to the character of ration.

47. Fed Holstein skimmilk carrying approximately 8.8 percent total solids with earth; increased in weight from 11.8 pounds to 31.3 pounds; small pig at outset but healthy; normal condition on slaughter, but not fat.

49. Fed Jersey skimmilk carrying approximately 9.8 percent total solids without earth; in apparently good condition at outset; increased in weight

from 19 to 22 pounds in 22 days; sick June 5, died June 7; death due to poisoning of the system occasioned by extreme constipation caused in this case by sawdust bedding, which had been carried from the pig's feet into the milk. Instead of acting as does earth to promote peristalsis, it caused complete intestinal stoppage; no samples taken or analyzed.

50. Fed Jersey skimmilk carrying approximately 9.8 percent fat with earth; increased in weight from 18.3 to 44 pounds, a very satisfactory gain; normal condition.

51. Fed Jersey milk carrying approximately 12.4 percent total solids and 2.7 percent fat without earth; increased in weight from 15.5 to 32 pounds, making excellent gains at first, but less satisfactory ones during the last week. No apparent cause developed on post mortem for falling off in live weight.

52. Fed Jersey milk carrying approximately 12.4 percent total solids and 2.7 percent fat with earth; increased in weight from 14.3 to 34 pounds, making prompt and satisfactory gains throughout entire run including last week, when it increased 5 pounds in weight as against 1.4 pounds gained by its mate which received no earth; in excellent condition on slaughter.

53. Fed Jersey milk carrying approximately 15 percent total solids and 5.3 percent fat without earth; increased in weight from 22.1 to 43.8 pounds, making very rapid gains at first but less rapid ones later, increasing but 2 pounds in weight during the last week; vitality low; no organic lesions.

54. Fed Jersey milk carrying approximately 15 percent total solids and 5.3 percent fat with earth; increased in weight from 18.3 to 47.5 pounds; in good health; condition normal at slaughter.

48 and 55. Check pigs.

1909. RUN E (56-62) (WASHBURN)

Bought of Heart's Delight Farm, Chazy, N. Y.; small lot used owing to inability to secure a larger lot of suitable size; high grade Chester-Whites; fed 62 days; June 26-August 26; entered test in good condition and larger and probably older than those used in preceding runs; grade Jersey herd-milk fed to all, Nos. 60, 61 and 62 receiving, in addition, subsoil earth freely.

Object: To test the value of earth added to a milk diet.

56. Fed Jersey skimmilk carrying approximately 9.4 percent total solids; increased in weight from 31 to 70 pounds, making slow gains at first, but more rapid ones thereafter; was fed castor oil on July 13 and 15 for constipation, this being often effective with pigs receiving skimmilk; in normal condition on slaughter.

57. Fed Jersey milk carrying approximately 12.2 percent total solids and 2.8 percent fat; increased in weight from 29 to 75.7 pounds, making good growth from the start; off feed July 25, 26; castor oil fed July 26 and 27 and earth July 27, 28, 31; in fair condition at slaughter.

58. Fed Jersey milk carrying approximately 15.2 percent total solids and 5 percent fat; increased in weight from 21 to 41 pounds in 56 days; gained in weight rather slowly, due to frequent illness; was greedy for food at first but soon became surfeited, ate little, became constipated; castor oil was administered frequently from July 13 onwards, sometimes together with alcohol as a stimulant, but was ineffective; animal seemed to be already saturated with grease; became peevish, sluggish, ears purple, and near death when on July 22, moist subsoil earth was fed and greedily consumed, though he would take no milk, much less castor oil, of his own accord; this induced thorough evacuation; pig was then placed on a skimmilk and earth diet for a few days, then on a 2.5 percent milk and earth diet; impossible to raise to a straight 5 percent milk diet; continued to do poorly and died August 20; in poor condition at death.

59. Check pig.

60. Fed Jersey skimmilk carrying approximately 9.4 percent total solids and earth; increased in weight from 29 to 69 pounds; made good gain from the start and kept in perfect health; in tip-top, fighting trim at slaughter; gave the slaughtering laboratory force a good scrap before succumbing to chloroform; carcass not fat.

61. Fed Jersey milk carrying approximately 12.2 percent total solids and 2.8 percent fat and earth; increased in weight from 25 to 79 pounds, making

prompt and regular gains; healthy throughout; a beautiful, vigorous animal; normal condition.

62. Fed Jersey milk carrying approximately 15.2 percent total solids and 5 percent fat and earth; increased in weight from 22 to 42.2 pounds; after a slow start made reasonably rapid gains for 4 weeks, then much slower gains, increasing but 3 pounds during the last two weeks as compared with 15 pound gain made by No. 61.

1909. RUN F (63-76) (WASHBURN)

Pure-bred Chester-Whites, two litters (63-69; 70-76) by the same sire. From Heart's Delight Farm, Chazy, N. Y. Most uniform 7 from each litter secured; 4 to 5 weeks old and in good condition when entered on experiment, October 13; fed 38 days (64, 67, 70, 72, 75) 58 days (63, 68, 71, 73, 74); died (65, 66); all pigs fed earth freely.

Object: Same as Run A.

63. Fed Holstein skimmilk carrying approximately 8.7 percent total solids; increased in weight from 20.8 pounds to 57.4 pounds, making satisfactory and consistent though not rapid gains; sound and normal.

64. Fed Holstein skimmilk carrying approximately 8.7 percent total solids; increased in weight from 22.8 to 44.3 pounds; lean but healthy and normal.

65. Fed Holstein milk carrying approximately 11.2 percent total solids and 2.4 percent fat; increased in weight from 15 to 49.3 pounds at death: made very satisfactory gains; was an extremely thrifty animal, so greedy that when the attendant carelessly overfed him he ate so much as to cause death November 26. On post mortem it was observed that the inner stomatic walls had parted, allowing the great mass of milk almost to enter the abdominal cavity being kept therefrom only by the outer stomatic walls.

66. Fed Holstein milk carrying approximately 11.2 percent total solids and 2.4 percent fat; increased in weight from 18 to 39 pounds at death; made unusually rapid gains until November 16, when it died of over-feeding, the animal being so greedy that he consumed too much and too rapidly.

67. Fed Holstein milk carrying approximately 13.2 percent total solids and 4.5 percent fat; increased in weight from 19 to 34.3 pounds; made good gains at first, but lost weight during the last week; was several times off feed; no abnormal condition observed.

68. Fed Holstein milk carrying approximately 13.2 percent total solids and 4.5 percent fat; increased in weight from 19.8 to 78.5 pounds; made good gains throughout the entire period; was a very robust animal; normal at slaughter.

70. Fed Jersey skimmilk carrying approximately 9.5 percent total solids; increased in weight from 23.8 to 52.9 pounds; made good growth; lean but strong.

71. Fed Jersey skimmilk carrying approximately 9.5 percent total solids; increased in weight from 20 to 67.5 pounds; made good gains throughout; sound when slaughtered.

72. Fed Jersey milk carrying approximately 12.1 percent total solids and 2.6 percent fat; increased in weight from 19.6 to 48.8 pounds; made very good gains; healthy, sound throughout and handsome.

73. Fed Jersey milk carrying approximately 12.1 percent total solids and 2.6 percent fat; increased in weight from 20.9 to 79.8 pounds, making very good gains throughout entire period; sound at slaughter.

74. Fed Jersey milk carrying approximately 14.5 percent total solids and 5 percent fat; increased in weight from 20 to 85.5 pounds, making very rapid and continuous gains; normal at slaughter.

75. Fed Jersey milk carrying approximately 14.5 percent total solids and 5 percent fat; increased in weight from 20.5 to 47.8 pounds, a fair gain; very vigorous pig; normal at slaughter.

69 and 76. Check pigs.

1910. RUN G (77-90) (WASHBURN)

Pure-bred Chester-Whites, from Heart's Delight Farm, Chazy, N. Y.: pick of two litters; arrived in good condition April 30; experimental feeding

began May 1; fed 61 days; slaughtered June 30; all sound and vigorous; the four fed skimmilk were dry and lean throughout, those fed medium grade milk in fine shape, sound and lusty, those fed rich milk healthy but somewhat over fat and less vigorous and lusty; all fed earth freely.

Object: Same as Run A.

77. Fed Holstein skimmilk carrying approximately 9.4¹ percent total solids; increased in weight from 25.5 to 60 pounds; normal at slaughter.

78. Fed Holstein skimmilk carrying approximately 9.4¹ percent total solids; increased in weight from 26 to 59 pounds; normal at slaughter.

79. Fed Holstein milk carrying approximately 11.5 percent total solids and 2.3 percent fat; increased in weight from 26 to 86 pounds; normal at slaughter.

80. Fed Holstein milk carrying approximately 11.5 percent total solids and 2.3 percent fat; increased in weight from 27.5 to 77 pounds; normal at slaughter.

81. Fed Holstein milk carrying 13 percent total solids and 3.9 percent fat; increased in weight from 29 to 100 pounds; sound but so fat that at slaughter it could neither struggle, squeal nor otherwise show vigor.

82. Fed Holstein milk carrying 13 percent total solids and 3.9 percent fat; increased in weight from 28.5 to 95 pounds; too fat to struggle materially when anesthetized.

84. Fed Jersey skimmilk carrying 9.7 percent total solids; increased in weight from 18.5 to 55 pounds; healthy except for short period of diarrhoea caused apparently by taking cold; normal throughout at slaughter.

85. Fed Jersey skimmilk carrying approximately 9.7 percent total solids; increased in weight from 21 to 56 pounds; normal at slaughter.

86. Fed Jersey milk carrying approximately 12.2 percent total solids and 2.7 percent fat; increased in weight from 24 to 77 pounds; very nearly perfect pig; normal at slaughter.

87. Fed Jersey milk carrying approximately 12.2 percent total solids and 2.7 percent fat; increased in weight from 25 to 81 pounds; normal at slaughter.

88. Fed Jersey milk carrying approximately 14.3 percent total solids and 5 percent fat; increased in weight from 25.5 to 86.5 pounds; made excellent gains at first and maintained them fairly well until the end of test, although several times off-feed and affected with diarrhoea or constipation.

89. Fed Jersey milk carrying approximately 14.3 percent total solids and 5 percent fat; increased in weight from 26 to 78.5 pounds; unsatisfactory gains toward the last; in low state of vitality.

83 and 90. Check pigs.

Considerable doubt is cast upon the outcome of run G. The analyses of the milk indicate carelessness or worse on the part of the attendant in charge of the feeding of this particular lot. It is difficult to believe that the samples of skimmilk purporting to be of Holstein origin are truly such, since nine composite samples range from 9.2 to 9.5 percent total solids, whereas the Holstein skimmilk used in preceding runs analyzed 8.7 or 8.8 percent. This skimmilk more closely resembled herd skimmilk, the strictly Jersey samples ranging from 9.4 to 9.8 percent. Furthermore, the standardization of the Holstein 5 percent milk was woefully bungled, it being but once in nine samples as high as 4.5, but thrice above 4 percent and twice almost as low as 3 percent. This situation throws doubt upon the records of Nos. 77, 78, which probably were fed more total solids than they should have received, and Nos. 81 and 82, which received a much lower grade of milk than they should have had.

1910. RUN H (91-111) (WASHBURN)

Pure-bred Chester-Whites from Heart's Delight Farm, Chazy, N. Y. Three litters arrived in good condition June 29; held on skimmilk until July 9, when they were started in good condition; fed 53 or 54 days; slaughtered August 30, 31. All received earth freely.

¹ It seems difficult to believe that the ration fed Nos. 77 and 78 was actually Holstein skimmilk, since it carried a much higher total solid content than any other lot used in any other run.

Object: To test effect of homogenization and the possibility of the utilization of vegetable oils homogenized. One (96) fed normal low-fat milk; one (95) normal high-fat milk; two (91, 108) homogenized low-fat milk; two (93, 109) homogenized high-fat milk; two (98, 105) homogenized corn oil and skimmilk with low-fat contents; two (99, 107) homogenized corn oil and skimmilk with high-fat contents; two (92, 101) fed normal milk starting low in solids and fat and increasing therein; three (94, 102, 110) homogenized milk starting low in solids and fat and increasing therein; three (100, 103, 106) homogenized corn oil and skimmilk, starting low in solids and fats and increasing therein.

96. Fed normal milk carrying approximately 12.2 percent total solids and 3 percent fat. Started and kept for one week on normal milk carrying approximately 14 percent total solids and 5 percent fat; being found unable to endure so rich a diet, shifted with 95 and placed from thence onwards on grade indicated above; kept in good condition throughout; increased in weight from 29 to 68.6 pounds; normal at slaughter.

108. Fed homogenized milk carrying approximately 11.5 percent total solids and 2.3 percent fat; increased in weight from 34 to 75.3 pounds; record negative throughout; normal at slaughter.

91. Fed homogenized milk carrying approximately 11.5 percent total solids and 2.3 percent fat; increased in weight from 26 to 72.9 pounds; record negative throughout; normal at slaughter.

98. Fed skimmilk and homogenized corn oil testing approximately 11.7 percent total solids and 2.6 percent fat; did not take to food as readily as pigs fed normal or homogenized milks; increased in weight from 36.3 to 89.2 pounds; made good growth throughout; in good condition at slaughter.

105. Fed skimmilk and homogenized corn oil, testing approximately 11.7 percent total solids and 2.6 percent fat; did not eat ration as readily as pigs fed normal or homogenized milks; increased in weight from 38.7 to 87.6 pounds; made good growth; in good condition at slaughter.

95. Fed normal milk carrying approximately 14.5 percent total solids and 5.5 percent fat; kept one week on milk carrying approximately 12 percent total solids and 3 percent fat and transferred to diet stated (see No. 96 record above); increased in weight from 27.3 to 77 pounds; made good growth throughout; no sick record; in good condition on slaughter.

109. Fed homogenized milk carrying approximately 13.4 percent total solids and 4.4 percent fat; no record of sickness or being off-feed; increased in weight from 37.3 to 89.9 pounds; made good growth throughout; in good condition at slaughter.

93. Fed homogenized milk carrying approximately 13.4 percent total solids and 4.5 percent fat; negative record; increased in weight from 30.3 to 90.6 pounds; made good growth; in good condition at slaughter.

99. Fed skimmilk and homogenized corn oil testing approximately 13.4 percent total solids and 4.4 percent fat; increased in weight from 37.3 to 91.9 pounds; made good growth throughout; no sick record; sound at slaughter; flesh flabby.

107. Fed skimmilk and homogenized corn oil testing approximately 13.5 percent total solids and 4.5 percent fat; increased in weight from 36 to 92.2 pounds; made good growth throughout; negative record; sound at slaughter; flesh flabby.

92. Fed normal milk at the outset for two days carrying approximately 11.5 percent total solids and 2.4 percent fat; increased in grade until on July 15, 6 days after experimental feeding began, a 15.2 percent total solids and 6.2 percent fat grade was being fed; increased yet further beginning July 19 until July 22 and thereafter a 17 percent total solids and 8.3 percent fat grade was fed; increased in weight from 28.3 to 78.6 pounds; made good gains at first, moderate gains thereafter; not an active pig; seemed usually rather stupid; ate food regularly but spent most of his time lying contentedly; off-feed August 28 to such an extent that water only was fed; allowed liberty of the runway for exercise; fasting and exercise seemed to improve its health, as vigor returned quickly; over-fat but otherwise in satisfactory condition at slaughter.

101. Fed normal milk at the outset for two days, carrying approximately 11.5 percent total solids and 2.4 percent fat; increased in grade until on July 15, 6 days after experimental feeding began, a 15.2 percent

total solids and 6.2 percent fat grade was being fed; increased yet further beginning July 19 until July 22 and thereafter until August 5 a grade of 17 percent total solids and 8.3 percent fat was fed; on August 5 and thereafter a grade of 18.9 percent total solids and 10.5 percent fat was fed; a more vigorous animal than its mate (92), yet lacked vigor; ate sparingly; gained well from 39 to 95.3 pounds; fairly healthy; very fat at slaughter.

94. Fed homogenized milk at the outset for two days, carrying approximately 11.5 percent total solids and 2.4 percent fat; increased in grade until on July 15, 6 days after experimental feeding began, a 13.9 percent total solids and 5 percent fat grade was being fed; increased yet further beginning July 19 until July 22 and thereafter a 15.3 percent total solids and 6.6 percent fat grade was fed; increased in weight from 32.7 to 97.1 pounds, an excellent gain; lacked vigor; overfat at slaughter.

110. Fed homogenized milk at outset carrying approximately 11.5 percent total solids and 2.4 percent fat; increased in grade until July 15, 6 days after experimental feeding began, a 13.9 percent total solids and 5 percent fat was fed, followed within a few days by a 15.1 percent total solids and 6.3 percent fat grade and by August 5 and thereafter a 17.2 percent total solids and 8.5 percent fat grade; off-feed for two days two weeks before slaughter; given water only and exercise; recovered; healthy but over-fat; otherwise normal at slaughter.

102. Fed homogenized milk at the outset carrying approximately 11.5 percent total solids and 2.4 percent fat; increased in grade until July 15, 6 days after experimental feeding began, a 13.9 percent total solids and 5 percent fat was fed, followed within a few days by a 15.1 percent total solids and 6.3 percent fat grade and by August 5 and thereafter a 17.2 percent total solids and 8.5 percent fat grade; healthy but over-fat; otherwise normal at slaughter.

100. Fed skim milk and homogenized corn oil testing at the outset approximately 13.2 percent total solids and 4.7 percent fat; after two days' preliminary feeding on a grade approximately 2.5 percent fat; increased yet further beginning July 19 and from July 22 onwards a 15.4 percent total solids and 6.7 percent fat grade was being fed; after August 5 it was raised to a grade approximately 17.6 percent total solids and 9.3 percent fat and during the last week of 18.2 percent total solids and 10 percent fat; increased in weight from 39.7 to 94.5 pounds; off-feed August 17 for a day; over-fat but not ill at slaughter.

106. Fed skim milk and homogenized corn oil testing at the outset approximately 13.2 percent total solids and 4.7 percent fat; after two days' preliminary feeding on a grade approximately 2.5 percent fat; increased yet further beginning July 19 and from July 22 onwards a 15.4 percent total solids and 6.7 percent fat grade was being fed; after August 5 it was raised to a grade approximately 17.6 percent total solids and 9.3 percent fat and during the last week of 18.2 percent total solids and 10 percent fat; increased in weight from 43.3 to 104.9 pounds; stronger animal than its mate; less affected by rich diet; over-fat at slaughter.

103. Fed skim milk and homogenized corn oil testing at the outset approximately 13 percent total solids and 4.7 percent fat, after two days' preliminary feeding on a grade approximately 2.5 percent fat; increased yet further beginning July 19 and from July 22 onwards a grade approximating 15.5 percent total solids and 6.9 percent fat was fed; increased in weight from 33.3 to 71.3 pounds; July 19 appeared unhealthy, not eating heartily, somewhat diarrhoeal; recovered in a day or two on skim milk.

Throughout this run all pigs fed milk testing 2.3 to 3 percent fat did well; all those fed milk testing 4.5 to 5.5 percent fat did less well; all those fed high-fat milk, 6.5 to 10.5 percent fat, became over-fat, suffered from various intestinal complaints or otherwise sickened, though not very severely, and at times refused their rations. The pigs fed corn oil took less readily to the ration than those fed normal or homogenized milk, whereas no particular difference was noticeable in this respect as between the normal and homogenized groups; all pigs in this run lived until normal slaughter period.

97, 104, 111. Check pigs.

RUN J (111-124) (WASHBURN)

Pure-bred Chester-Whites from Heart's Delight Farm, Chazy, N. Y., from two litters farrowed August 10; received in good condition September 10; started on experimental feeding September 12; fed 67 days; slaughtered November 18; all received earth freely.

Object: Same as Run H.

Nos. 111, 114, 118, 121, fed normal milk; Nos. 112, 115, 119, 122, homogenized milk; and Nos. 113, 116, 120, 123, homogenized corn oil and skimmilk. The rations of all the pigs were increased in quantity up to the limit of their ability to consume, then the quantity was held constant, and the fat content increased to the limit of their endurance, when it was reduced in order to enable them to make growth; later on it being again increased in order to test the effect of the different milks. All did almost uniformly well while being fed low-fat and almost uniformly ill while being fed high-fat rations; those on normal milk apparently did the best, those on homogenized milk next best, and those on corn oil least well. All were kept in sufficiently normal condition to be slaughtered at the regularly appointed time, when all were found to be sufficiently healthy to warrant use of data obtained.

117, 124. Check pigs.

111. Fed normal milk constructed from skimmilk and cream carrying, as judged by composite samples, approximately 12 percent total solids and 3 percent fat from September 12 to 19; approximately 14.4 percent total solids and 5.1 percent fat from September 19 to 23 and from that date until late in October approximately 16.5 percent total solids and 7.7 percent fat, when it was dropped again to approximately 14.4 percent total solids and 5.2 percent fat, to be later, about November 1, raised to approximately its former grade; increased in weight from 11 to 41 pounds; normal record; normal at slaughter.

112. Fed homogenized milk constructed from skimmilk and cream carrying, as judged by composite samples, approximately 11.6 percent total solids and 2.6 percent fat from September 12 to 23; from September 23 to October 15 approximately 15.2 percent total solids and 6.5 percent fat; from October 15 to slaughter approximately 13.5 percent total solids and 4.2 percent fat; increased in weight from 11 to 41 pounds; slightly off-feed September 19, 20; normal record; normal at slaughter.

113. Fed skimmilk and homogenized corn oil testing as judged by composite samples approximately 12.8 percent total solids and 4 percent fat from September 12 to 23; approximately 14.8 percent total solids and 6.7 percent fat from September 23 to October 15; approximately 13.1 percent total solids and 4.3 percent fat from October 15 to slaughter; increased in weight from 11.5 to 43 pounds; normal at slaughter.

114. Fed normal milk precisely as was No. 111; increased in weight from 12.5 to 46.5 pounds; normal at slaughter.

115. Fed homogenized milk precisely as was No. 112; increased in weight from 10 to 42 pounds; normal at slaughter.

116. Fed homogenized skimmilk and corn oil precisely as was No. 113; increased in weight from 11.5 to 39 pounds; off-feed and constipated November 1-3; normal at slaughter.

118. Fed normal milk precisely as was No. 111; increased in weight from 13 to 44 pounds; off-feed October 22; normal at slaughter.

119. Fed homogenized milk precisely as was No. 112; increased in weight from 13 to 39.5 pounds; normal throughout; normal at slaughter.

120. Fed homogenized skimmilk and corn oil precisely as was No. 113; increased in weight from 15 to 32.5 pounds; off-feed and ill October 25; on November 12 it was again doing poorly, and did poorly until slaughter; normal at slaughter.

121. Fed normal milk precisely as was No. 111; increased in weight from 13 to 41 pounds; normal throughout; normal at slaughter.

122. Fed homogenized milk precisely as was No. 112; increased in weight from 13.5 to 32 pounds; went off-feed October 24 and thereafter was backward and did poorly; normal at slaughter.

NOTE. Through inadvertence number 111 was twice used on check pig in Run H and this pig in Run J.

123. Fed homogenized skimmilk and corn oil precisely as was No. 113; increased in weight from 11 to 37.5 pounds; refused feed October 2, being diarrhoeal; again refused feed October 4; put on skimmilk for two days, then returned to original rich diet, but again put on skimmilk October 10 and worked back to original diet by October 16; slightly ill again November 14; normal at slaughter.

1911. RUN K (126-146) (WASHBURN)

Pure-bred Chester-Whites from Heart's Delight Farm, Chazy, N. Y.; from three litters farrowed February 23, 26, 27; received April 19 in good condition; experimental feeding began April 20; fed 51 or 52 days; slaughtered June 9, 10, all being in normal condition; all fed earth freely.

The purpose of this particular trial was to furnish a check on previous runs (A-J), to secure a norm derived from feeding a sufficient number of pigs fed an approximation to an ideal ration, one at least composed of approved feeding stuffs and fed in judicious quantities; as well as to test milk variation effects. Three (126, 133, 140) pigs received skimmilk; three, (127, 134, 141) milk testing approximately 2.5 percent fat, but reduced with water to a total solid standard approximately equivalent to that of the skimmilk; three (128, 135, 142) normal milk standardized to carry approximately 2.5 percent fat; three (129, 136, 143) a normal milk testing approximately 2.5 percent fat to which gelatin was added; three (130, 137, 144) a ration consisting of skimmilk identical with that fed the first 3 to which a "grain adjunct" was added; and three (131, 138, 145) normal milk carrying approximately 2.5 percent fat to which a "grain adjunct" was added.

132, 139, 146, Check pigs. (Note. No. 125 non-existent).

126. Fed skimmilk carrying approximately 9.7 percent total solids; made moderate gains for 3 weeks, thereafter increasing and gaining moderately at the last; increased in weight from 24.3 to 40.6 pounds; lean, muscular and thoroughly healthy.

133. Fed skimmilk carrying approximately 9.7 percent total solids; gains resembled No. 126; increased in weight from 18.4 to 35.4 pounds; lean, but perfectly healthy.

140. Fed skimmilk carrying approximately 9.7 percent total solids; increased in weight from 20.6 to 39.6 pounds; in perfect condition at slaughter.

127. Fed milk reduced with water, carrying approximately 9.1 percent total solids and 1.9 percent fat; lost weight during the first week, regained it in the second and made good gains thereafter; increased in weight from 22.4 to 39.5 pounds; in fair form; in good condition at slaughter.

134. Fed milk reduced with water carrying approximately 9.1 percent total solids and 1.9 percent fat; increased in weight from 21.5 to 44.5 pounds; in very good form; in good condition at slaughter.

141. Fed milk reduced with water carrying approximately 9.1 percent total solids and 1.9 percent fat; lost weight during the first week, regained it in the second and thereafter made good gains; increased in weight from 22.3 to 41 pounds; in good form; in good condition at slaughter.

128. Fed milk carrying approximately 12 percent total solids and 2.6 percent fat; gained regularly; increased in weight from 20 to 46 pounds; in excellent condition; in perfect health at slaughter.

135. Fed milk carrying approximately 12 percent total solids and 2.6 percent fat; gained slowly at the outset, thereafter doing better and gaining rapidly towards the close; increased in weight from 21.3 to 44.6 pounds; in excellent form; in perfect health at slaughter.

142. Fed milk carrying approximately 12 percent total solids and 2.6 percent fat; gained slowly at first and rapidly thereafter; increased in weight from 20.4 to 44.8 pounds; in excellent form; in perfect health at slaughter.

129. Fed milk carrying approximately 12 percent total solids and 2.6 percent fat plus gelatin; lost weight at first; regained it in the third week and gained fairly thereafter; increased in weight from 21.1 to 40.5 pounds; in fairly good form; in good health when killed.

136. Fed milk carrying approximately 12 percent total solids and 2.6 percent fat plus gelatin; light in weight at start, but began gaining promptly;

made excellent use of food; increased in weight from 16.5 to 38.9 pounds; finished in good form for poor start; in good health when slaughtered.

143. Fed milk carrying approximately 12 percent total solids and 2.6 percent fat plus gelatin; made prompt gains and finished in good form; increased in weight from 17.1 to 41.8 pounds; healthy when slaughtered.

130. Fed skimmilk carrying approximately 9.7 percent total solids to which was added a "grain adjunct" consisting of from 60 to 77 percent corn meal and from 20 to 11 percent of brown middlings and from 20 to 11 percent old process linseed oil meal; showed diarrhoea for one day; gained from the first and rapidly towards end; increased in weight from 19.1 to 54.1 pounds; finished in excellent form; vigorous, sound throughout.

137. Fed skimmilk carrying approximately 9.7 percent total solids to which was added a "grain adjunct" of corn meal, brown middlings and linseed oil meal as indicated with No. 130; light in weight at start, but began gaining promptly and rapidly towards close; increased in weight from 14.6 to 53.1 pounds; finished exceptionally well; sound throughout; beautiful animal.

144. Fed skimmilk carrying approximately 9.7 percent total solids to which was added a "grain adjunct" of corn meal, brown middlings and linseed oil meal as indicated with No. 130; gained rapidly towards close and finished in exceptionally good condition; increased in weight from 19.5 to 56.8 pounds; sound, beautiful throughout.

131. Fed milk carrying approximately 12 percent total solids and 2.6 percent fat to which was added a "grain adjunct" of corn meal, brown middlings and linseed oil meal as indicated with No. 130; made large gains from the outset; increased in weight from 22.5 to 69.4 pounds; finished in excellent form; sound and beautiful animal.

138. Fed milk carrying approximately 12 percent total solids and 2.6 percent fat to which was added a "grain adjunct" of corn meal, brown middlings and linseed oil meal as indicated with No. 130; gained promptly from the start and very rapidly towards close; finished in good form, though not as heavy as some; increased in weight from 17.3 to 54.3 pounds; thoroughly sound when slaughtered.

145. Fed milk carrying approximately 12 percent total solids and 2.6 percent fat to which was added a "grain adjunct" of corn meal, brown middlings and linseed oil meal as indicated with No. 130; made excellent gains from the start and very rapidly towards close; finished in prime form; increased in weight from 16.1 to 57.4 pounds; sound and beautiful throughout at time of slaughter.

The last six pigs, 130, 137, 144, 131, 138, 145, were those so fed as to serve as checks upon the composition found previously to exist in pigs fed purely upon milk. It will be of interest further to observe the weight and quality gained as between skimmilk plus grain and the 2.5 percent milk plus grain. Inasmuch as the total solid contents, that is to say the total solids derived from the milk plus those of grain origin, were held practically identical with the two groups. The same nutritive ratios were maintained, the heat producing constituent being derived more largely in one case from fat and in the other from grain.

1911. RUN L (147-167) (WASHBURN)

Pure-bred Chester-Whites from Heart's Delight Farm, Chazy, N. Y.: from three litters farrowed May 17 and 19, two litters being sired by same boar; entered trials in good condition June 22, fed for 50, 51 days; slaughtered August 10, 11; earth fed to all freely.

153, 160, 167. Check pigs.

Object: To determine the worth of sweetened and unsweetened (the so-called evaporated) condensed milks as compared with normal milk in infant feeding. Two from each litter—6 in all—(147, 154, 161, 148, 155, 162) were fed normal milk carrying approximately 12.8 percent total solids and 3.4 percent fat; two from each litter—6 in all—(149, 156, 163, 150, 157, 164) were fed on plain, that is to say, unsweetened, sterilized, condensed milk so reduced with water, roughly half and half, that the total solids and fat contents approximated those present in the normal milk as fed; and two pigs from each litter—6 in all—(151, 158, 165, 162, 159, 166) were fed on sweetened.

condensed milk reduced with water, one part milk to four to five parts water, so as to yield a ration with total solids content approximately that of the normal milk as fed. Further, this run tested the ability of young animals to make use of inorganic tricalcic phosphate as bone strengthening material; consequently three pigs of each of the three groups were fed this material.

147. Fed normal milk carrying approximately 12.8 percent total solids and 3.4 percent fat; gained from the start; finished in excellent form; increased in weight from 13.2 to 40.5 pounds.

154. Fed normal milk carrying approximately 12.8 percent total solids and 3.4 percent fat; made good growth from the beginning; increased in weight from 14.5 to 37.5 pounds; trace of diarrhoea July 3; sound, healthy, normal at slaughter.

161. Fed normal milk carrying approximately 12.8 percent total solids and 3.4 percent fat; gained from the beginning, but moderately towards the end; increased in weight from 13.4 to 35 pounds; individually not so good an animal as No. 147; suffered some from diarrhoea between June 27 and July 12, but not seriously; otherwise in fair health; healthy at slaughter.

148. Fed normal milk carrying approximately 12.8 percent total solids and 3.4 percent fat plus calcium phosphate; increased in weight from 14 to 35 pounds; was healthy throughout the test, save slight diarrhoea on July 12.

155. Fed normal milk carrying approximately 12.8 percent total solids and 3.4 percent fat plus calcium phosphate; gained from the beginning though not as rapidly towards the close as some; increased in weight from 15.7 to 32.5 pounds; good strong animal.

162. Fed normal milk carrying approximately 12.8 percent total solids and 3.4 percent fat plus calcium phosphate; gained little the first week and more rapidly thereafter; closed in good shape considering start; increased in weight from 13.3 to 37.5 pounds; healthy throughout the test, save that slight diarrhoea appeared June 27 and July 12.

149. Fed unsweetened, sterilized condensed milk carrying approximately 12.4 percent total solids and 3.5 percent fat; gained little the first week and more rapidly towards the close; increased in weight from 16.1 to 43 pounds; ended in good condition; normal at slaughter.

156. Fed unsweetened sterilized condensed milk carrying approximately 12.4 percent total solids and 3.5 percent fat; gained little the first week and better thereafter; increased in weight from 17.1 to 42.5 pounds; finished in only fair form; healthy.

163. Fed unsweetened, sterilized, condensed milk carrying approximately 12.4 percent total solids and 3.5 percent fat; gained none the first week; began improving the second; increased in weight from 15.5 to 39 pounds; finished fairly well; normal at slaughter.

150. Fed unsweetened, sterilized, condensed milk carrying approximately 12.4 percent total solids and 3.5 percent fat plus calcium phosphate; began comparatively light; gained little first week, did better thereafter; increased in weight from 14.1 to 38 pounds; finished in fair condition; healthy throughout.

157. Fed unsweetened, sterilized, condensed milk carrying approximately 12.4 percent total solids and 3.5 percent fat plus calcium phosphate; started above the average, gained well, finished in good form; increased in weight from 17.3 to 41.8 pounds; remained healthy throughout; in good condition at slaughter.

164. Fed unsweetened, sterilized, condensed milk carrying approximately 12.4 percent total solids and 3.5 percent fat plus calcium phosphate; gained from the start; increased in weight from 14.7 to 39 pounds; finished in good condition; suffered slightly from diarrhoea on July 5 and 11; normal at slaughter.

151. Fed sweetened, condensed milk carrying approximately 12.2 percent total solids and 1.7 percent fat, plain; gained from the start; increased in weight from 15.3 to 32.5 pounds; finished in fair condition; slight diarrhoea July 12 and 14; healthy at slaughter.

158. Fed sweetened condensed milk carrying approximately 12.2 percent total solids and 1.7 percent fat, gained moderately; increased in weight from 15.1 to 31.3 pounds; finished in fair condition; healthy at slaughter.

165. Fed sweetened condensed milk carrying approximately 12.2 percent total solids and 1.7 percent fat; gained slowly; increased in weight from 12.7 to 30 pounds; finished in fair condition; had slight digestive trouble during test; feces offensive; normal at slaughter.

152. Fed sweetened condensed milk carrying approximately 12.2 percent total solids and 1.7 percent fat plus calcium phosphate; began very light in weight; gained little the first week and slightly more the second, did better thereafter; increased in weight from 12.1 to 28 pounds; finished in poor form; troubled much of the time with hoarseness and an annoying cough; otherwise seemed thoroughly well; normal at slaughter.

159. Fed sweetened condensed milk carrying approximately 12.2 percent total solids and 1.7 percent fat plus calcium phosphate; gained little the first week, none the second, better thereafter; increased in weight from 17 to 31 pounds; finished light; apparently normal at slaughter.

166. Fed sweetened condensed milk carrying approximately 12.2 percent total solids and 1.7 percent fat plus calcium phosphate; gained from the start; increased in weight from 13.8 to 29.6 pounds; in fair form despite intestinal troubles and cough June 28 to July 11; finished in reasonable health; normal at slaughter.

THE BREAKING STRENGTH OF BONES—RUN L—1911

On September 8, nearly a month after slaughter, the strength of the femur bones of the pigs in Run L was ascertained. (Plate VIII).

TRICALCIC PHOSPHATE OMITTED

147. Normal milk; a small amount of dense bone work, the bony substance being thin and hollow on the inside of bone; medium size; broke with a long diagonal break and was badly shattered.

149. Unsweetened sterilized condensed milk; very large cavity on inside of bone; the bony substances thin; broke diagonally.

151. Sweetened condensed milk; badly shattered in breaking; hollow in bone, medium size; thickness of bone, medium.

154. Normal milk; broke transversely, very few jagged edges; large amount of bony tissue; very small cavity in inside of bone.

156. Unsweetened sterilized condensed milk; medium amount of bony tissue; medium hollow in bone; break diagonal; somewhat shattered.

158. Sweetened condensed milk; very thin bony structure; medium size cavity; diagonal break.

161. Normal milk; thin bony structure; medium size cavity; long diagonal break.

163. Unsweetened sterilized condensed milk; break almost square; jagged edges; medium amount of bony tissue; small cavity in bone.

165. Sweetened condensed milk; very thin bone; small cavity; long diagonal break.

TRICALCIC PHOSPHATE USED

148. Normal milk; medium amount of bony tissue; small cavity; break long diagonal.

150. Unsweetened condensed milk; bony tissue thick; clean-cut diagonal break; bone but slightly shattered.

152. Sweetened condensed milk; thin bony structure; small cavity; long diagonal break; bone not badly split up.

155. Normal milk; break almost at right angles; bone not split; large amount of bony tissue in inside cavity.

157. Unsweetened condensed milk; shows medium amount of bony tissue; medium size cavity; transverse break; somewhat split in breaking.

159. Sweetened condensed milk; break nearly at right angles; large amount of bony tissue; very small cavity in bone.

162. Normal milk; bony structure thick; cavity in bone small; long diagonal break.

164. Unsweetened condensed milk; break at right angles; no jagged edges; bony tissue thick; small cavity in bone.

166. Sweetened condensed milk; broke square in two with a few jagged edges; not split up; medium amount of bony tissue; small cavity.

ANALYTICAL DATA

SKIMMILK

Pig No.	34	37	47	50	56	60	63	64	70	71	77	78	84	85	133	140
Weight when killed, kilos..	22.56	18.52	14.42	19.42	33.14	32.99	25.63	20.02	23.38	29.41	27.46	26.80	24.92	23.74	17.57	19.50
Weight at start, kilos.....	8.21	6.96	5.34	8.32	14.07	13.17	9.42	10.33	10.78	9.08	11.58	11.80	8.40	9.53	8.34	9.36
Days fed	48	48	38	38	61	61	54	34	34	54	60	60	60	60	51	51
Average gain per day, grams	299	241	239	292	313	325	300	285	371	377	265	250	275	237	181	199
Composition of pig when killed:																
Dry matter, percent	37.51	32.55	29.28	33.73	35.99	36.78	32.62	30.40	34.76	40.63	36.26	36.87	35.28	36.93	26.28	26.92
Ash, percent	3.85	4.19	3.21	3.21	3.70	3.57	3.75	3.82	3.79	3.60	3.68	3.82	3.93	3.93	2.88	3.15
Protein, percent	16.29	16.83	15.38	14.75	16.50	16.56	17.26	16.00	16.38	16.31	16.63	16.75	16.56	16.06	15.19	15.63
Fat, percent	16.78	10.86	11.05	15.64	15.30	16.25	11.00	11.14	14.76	20.52	16.18	17.26	14.71	16.87	7.34	7.43
Ratio, protein to fat, 1:....	1.03	0.65	0.72	1.06	0.93	0.98	0.64	0.70	0.90	1.26	0.97	1.10	0.89	1.06	0.48	0.47
Composition of pig when feeding began:																
Dry matter, percent	25.32	25.32	30.37	31.25	34.33	34.33	29.99	29.99	37.02	37.02	35.37	35.37	36.58	36.58	32.02	30.93
Ash, percent	3.22	3.22	2.79	3.06	3.11	3.11	2.99	2.99	3.13	3.13	3.15	3.15	3.29	3.29	2.86	2.77
Protein, percent	16.56	16.56	14.19	15.31	13.88	13.88	14.81	14.81	14.63	14.63	15.81	15.81	15.63	15.63	15.81	15.06
Fat, percent	5.08	5.08	12.25	12.53	16.75	16.75	11.89	11.89	18.94	18.94	16.05	16.05	17.26	17.26	12.67	12.56
Ratio, protein to fat, 1:....	0.31	0.31	0.86	0.82	1.21	1.21	0.80	0.80	1.32	1.32	1.02	1.02	1.10	1.10	0.81	0.83
Food consumed, kilos	446.0	361.7	233.7	248.5	473.5	473.1	428.0	231.1	241.2	471.3	382.4	378.3	393.4	396.6	165.7	165.9
Composition of food:																
Dry matter, percent	9.40	9.40	8.56	9.84	9.37	9.37	8.76	8.76	9.50	9.50	9.41	9.41	9.69	9.69	9.79	9.79
Ash, percent	0.92	0.92	0.65	0.77	0.65	0.65	0.71	0.71	0.75	0.75	0.71	0.71	0.75	0.75	0.76	0.76
Protein, percent	3.96	3.96	3.02	3.97	3.76	3.76	3.33	3.33	4.12	4.12	3.74	3.74	4.05	4.05	3.97	3.97
Carbohydrate, percent	4.49	4.49	4.79	5.03	4.93	4.93	4.67	4.67	4.60	4.60	4.90	4.90	4.85	4.85	5.03	5.03
Fat	0.03	0.03	0.09	0.07	0.03	0.03	0.05	0.05	0.03	0.03	0.06	0.06	0.04	0.04	0.03	0.03

ANALYTICAL DATA

2.5 PERCENT MILK

Pig No.	38	39	45	51	52	57	61	65	72	73	79	80	86	87	96	128
Weight when killed, kilos ..	22.42	24.34	20.24	14.47	14.70	35.91	36.60	24.85	22.15	34.49	38.38	34.53	34.86	36.90	31.15	20.78
Weight at start, kilos	9.19	9.12	8.28	7.04	6.47	13.17	11.35	6.81	8.90	9.47	11.80	12.48	10.90	11.35	9.08	9.08
Days fed	48	48	38	38	38	61	61	41	34	54	60	60	60	60	52	51
Average gain per day, grams	276	317	315	196	217	373	414	440	390	463	443	203	400	426	424	229
Composition of pig when killed:																
Dry matter, percent	39.08	38.77	33.98	31.22	35.46	41.03	46.26	34.78	40.46	48.44	44.06	43.38	42.88	49.11	38.83	32.55
Ash, percent	3.64	3.58	2.91	3.00	2.91	3.29	3.13	3.39	4.07	3.26	3.44	3.27	3.30	3.16	3.80	2.98
Protein, percent	14.74	14.94	14.69	14.00	13.31	14.88	14.44	15.81	15.19	15.06	14.19	14.50	14.56	13.44	15.13	15.88
Fat, percent	20.53	20.12	16.38	14.13	19.29	22.62	28.58	16.35	21.44	29.39	26.54	26.64	24.77	31.59	19.59	13.24
Ratio protein to fat, 1:.....	1.39	1.35	1.12	1.01	1.45	1.52	1.98	0.97	1.41	1.95	1.87	1.77	1.34	2.41	1.29	0.83
Composition of pig when feeding began:																
Dry matter, percent	26.32	25.32	30.37	31.25	31.25	34.33	34.33	29.99	37.02	37.02	35.37	35.37	36.58	36.58	32.98	35.46
Ash, percent	3.22	3.22	2.79	3.06	3.06	3.11	3.11	2.99	3.13	3.13	3.15	3.15	3.29	3.29	3.52	3.12
Protein, percent	16.56	16.56	14.19	15.31	15.31	13.88	13.88	14.81	14.63	14.63	15.81	15.81	15.63	15.63	15.44	15.25
Fat, percent	5.08	5.08	12.25	12.53	12.53	16.75	16.75	11.89	18.94	18.94	16.05	16.05	17.26	17.26	13.78	17.71
Ratio, protein to fat, 1:.....	0.31	0.31	0.86	0.82	0.82	1.21	1.21	0.80	1.32	1.32	1.02	1.02	1.10	1.10	0.89	1.16
Food consumed, kilos	273.8	293.0	199.2	144.9	141.9	405.4	439.2	215.6	197.1	452.0	433.6	414.6	370.5	415.8	283.0	155.5
Composition of food:																
Dry matter, percent	12.21	12.21	11.06	12.25	12.25	12.12	12.12	11.16	12.09	10.91	11.50	11.50	12.19	12.19	12.22	12.08
Ash, percent	0.90	0.90	0.78	0.76	0.76	0.68	0.68	0.74	0.77	0.68	0.73	0.73	0.77	0.77	0.75	0.76
Protein, percent	3.92	3.92	2.90	3.94	3.94	3.68	3.68	3.32	3.99	3.67	3.67	3.67	3.98	3.98	3.78	3.79
Carbohydrate, percent	4.55	4.55	4.84	4.86	4.86	4.94	4.94	4.60	4.83	4.34	4.90	4.90	4.78	4.78	4.73	4.89
Fat, percent	2.84	2.84	2.54	2.69	2.69	2.82	2.82	2.50	2.50	2.30	2.20	2.20	2.66	2.66	2.96	2.64

2.5 PERCENT MILK

Pig No.	135	142	129	136	143	147	148	154	155	161	162
Weight when killed, kilos.....	22.24	21.29	20.35	19.46	20.95	19.91	16.73	18.42	15.32	17.28	18.62
Weight at start, kilos.....	9.65	9.25	9.59	7.49	7.78	5.99	6.35	6.58	7.13	6.08	6.04
Days fed.....	51	51	51	51	51	49	49	49	49	49	49
Average gain per day, grams.....	247	236	211	235	258	284	212	242	167	229	257
Composition of pig when killed:											
Dry matter, percent.....	33.39	31.53	32.29	31.91	31.26	32.10	31.43	31.07	38.95	31.02	31.67
Ash, percent.....	2.89	2.89	3.11	3.01	3.16	3.06	3.60	2.83	3.24	2.82	3.37
Protein, percent.....	14.50	15.21	12.94	13.06	14.38	15.66	15.38	15.56	14.13	14.75	15.88
Fat, percent.....	15.50	13.18	15.87	15.18	13.04	11.25	11.47	12.21	20.86	12.98	11.52
Ratio, protein to fat, 1:.....	1.07	0.87	1.23	1.16	0.91	0.72	0.75	0.78	1.47	0.88	0.72
Composition of pig when feeding began:											
Dry matter, percent.....	32.02	30.83	35.47	32.02	30.83	38.05	38.05	37.08	37.08	36.62	36.62
Ash, percent.....	2.86	2.77	2.84	2.86	2.77	2.51	2.51	2.55	2.55	3.09	3.09
Protein, percent.....	15.81	15.06	15.81	15.81	15.06	14.56	14.56	14.81	14.81	14.44	14.44
Fat, percent.....	12.67	12.66	15.44	12.67	12.56	20.36	20.36	19.24	19.24	17.87	17.87
Ratio, protein to fat, 1:.....	0.80	0.83	0.98	0.80	0.83	1.40	1.40	1.30	1.30	1.24	1.24
Food consumed, kilos.....	158.2	158.2	155.6	154.9	155.3	107.0	107.0	106.2	107.0	107.0	107.0
Composition of food:											
Dry matter, percent.....	12.08	12.08	12.08	12.08	12.08	12.72	12.72	12.72	12.72	12.72	12.72
Ash, percent.....	0.76	0.76	0.76	0.76	0.76	0.70	0.70	0.70	0.70	0.70	0.70
Protein, percent.....	3.79	3.79	3.79	3.79	3.79	3.57	3.57	3.57	3.57	3.57	3.57
Carbohydrate, percent.....	4.89	4.89	4.89	4.89	4.89	5.16	5.16	5.16	5.16	5.16	5.16
Fat, percent.....	2.64	2.64	2.64	2.64	2.64	3.29	3.29	3.29	3.29	3.29	3.29

ANALYTICAL DATA

FIVE PERCENT MILK

Pig No.	35	36	42	43	53	54	67	68	74	75	81	82	88	89	95
Weight when killed, kilos	18.04	21.61	24.88	19.50	19.78	20.60	15.02	35.66	39.24	21.50	44.77	42.85	38.13	35.12	34.96
Weight at start, kilos	9.01	8.29	10.74	8.58	10.02	8.29	8.63	8.97	9.08	9.31	13.17	12.94	11.58	11.80	9.08
Days fed	28	48	38	38	38	38	34	54	54	34	60	60	60	60	52
Average gain per day, grams..	322	278	372	287	267	324	188	494	559	359	527	499	443	389	498
Composition of pig when killed:															
Dry matter, percent	36.21	42.75	42.31	34.80	39.05	41.70	34.84	45.31	43.07	40.57	49.49	51.46	47.09	48.31	39.89
Ash, percent	3.04	3.49	3.22	2.70	2.78	2.46	4.35	3.31	3.19	3.66	2.93	2.95	3.27	2.81	3.14
Protein, percent	13.13	13.88	13.56	13.81	13.88	13.31	15.69	15.19	14.69	14.34	13.88	13.56	12.81	14.19	15.12
Fat, percent	19.74	24.43	25.61	18.42	23.19	25.93	14.88	26.93	26.69	33.11	32.76	34.92	31.03	31.38	21.32
Ratio, protein to fat, 1:	1.51	1.76	1.89	1.34	1.67	1.95	0.95	1.78	1.75	1.61	2.36	2.58	2.42	2.22	1.41
Composition of pig when feeding began:															
Dry matter, percent	25.32	25.32	30.37	30.37	31.25	31.25	29.99	29.99	37.02	37.02	35.37	35.37	36.58	36.58	32.98
Ash, percent	3.22	3.22	2.79	2.79	3.06	3.06	2.99	2.99	3.13	3.13	3.15	3.15	3.29	3.29	3.52
Protein, percent	16.56	16.56	14.19	14.19	15.31	15.31	14.81	14.81	14.63	14.63	15.81	15.81	15.63	15.63	15.44
Fat, percent	5.08	5.08	12.25	12.25	12.53	12.53	11.89	11.89	18.94	18.94	16.05	16.05	17.26	17.26	13.78
Ratio, protein to fat, 1:	0.31	0.31	0.86	0.86	0.82	0.82	0.80	0.80	1.32	1.32	1.02	1.02	1.10	1.10	0.89
Food consumed, kilos	141.0	213.1	211.1	158.1	131.8	163.0	102.2	297.7	305.3	131.9	425.1	425.4	313.3	303.8	255.6
Composition of food:															
Dry matter, percent	14.52	14.62	13.42	13.42	14.76	14.76	13.26	13.26	14.29	14.29	12.90	12.90	14.30	14.30	14.55
Ash, percent	0.88	0.88	0.68	0.68	0.73	0.73	0.74	0.74	0.74	0.74	0.72	0.72	0.74	0.74	0.73
Protein, percent	3.78	3.86	2.92	2.92	3.74	3.74	3.24	3.24	3.91	3.91	3.61	3.61	3.83	3.83	3.65
Carbohydrate, percent	4.68	4.58	4.81	4.81	5.10	5.10	4.78	4.78	4.81	4.81	4.80	4.80	4.72	4.72	4.61
Fat, percent	5.18	5.30	5.01	5.01	5.19	5.19	4.50	4.50	4.83	4.83	3.77	3.77	5.01	5.01	5.56

MILK HOMOGENIZED AT 85° F.

Pig No.	2.5% 108	Homo. 91	Corn oil 98	Corn oil 105	5% Homo. 109	93	Corn oil 99	Corn oil 107	Norm. 8% 92	101	94	Homo. 8% 102	110	Corn oil 103	100	106
Weight when killed, kilos ..	34.17	33.08	40.48	39.76	40.80	41.08	41.72	41.88	33.40	43.25	44.09	37.38	47.81	32.38	42.90	47.61
Weight at start, kilos	12.26	8.63	12.26	14.98	13.62	9.53	12.71	13.62	10.44	13.62	10.44	11.80	15.43	11.80	16.34	16.34
Days fed	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
Average gain per day, grams	421	470	543	477	523	607	558	544	442	570	647	492	623	396	510	601
Composition of pig when killed:																
Dry matter, percent	44.71	37.45	40.94	41.69	40.57	38.93	41.97	42.88	45.27	48.43	46.39	47.23	46.70	37.46	44.19	45.80
Ash, percent	3.17	3.31	3.48	3.31	3.41	3.32	3.38	3.03	3.10	2.76	2.89	2.55	3.02	3.09	3.10	2.63
Protein, percent	15.13	15.63	16.31	14.87	15.81	16.00	14.94	13.87	11.94	13.19	13.44	13.50	13.88	15.69	14.31	13.56
Fat, percent	26.56	18.25	21.00	23.31	21.34	19.37	23.70	25.45	30.09	32.45	31.07	31.37	29.83	18.16	26.32	29.44
Ratio, protein to fat, 1:	1.76	1.17	1.29	1.57	1.35	1.21	1.56	1.83	2.52	2.46	2.31	2.32	2.15	1.16	1.84	2.17
Composition of pig when feeding began:																
Dry matter, percent	32.62	32.62	35.46	35.46	32.62	32.62	35.46	35.46	32.98	32.98	32.62	32.62	32.62	35.46	35.46	35.46
Ash, percent	3.34	3.34	3.12	3.12	3.34	3.34	3.12	3.12	3.52	3.52	3.34	3.34	3.34	3.12	3.12	3.12
Protein, percent	15.63	15.63	15.25	15.25	15.63	15.63	15.25	15.25	16.44	16.44	16.63	16.63	16.63	16.25	16.25	16.25
Fat, percent	13.51	13.51	17.71	17.71	13.51	13.51	17.71	17.71	13.78	13.78	13.51	13.51	13.51	17.71	17.71	17.71
Ratio, protein to fat, 1:	0.86	0.86	1.16	1.16	0.86	0.86	1.16	1.16	0.89	0.89	0.86	0.86	0.86	1.16	1.16	1.16
Food consumed, kilos	329.8	273.2	330.1	327.8	319.0	318.1	319.6	318.8	264.8	272.9	318.9	299.3	283.9	224.5	299.9	298.7
Composition of food:																
Dry matter, percent	11.57	11.57	11.81	11.81	13.44	13.44	13.55	13.55	16.55	17.33	15.00	15.71	15.71	14.80	15.86	15.86
Ash, percent	0.75	0.75	0.75	0.75	0.74	0.74	0.75	0.75	0.73	0.71	0.73	0.72	0.72	0.71	0.70	0.70
Protein, percent	3.70	3.70	3.65	3.65	3.63	3.63	3.61	3.61	3.47	3.41	3.51	3.45	3.45	3.54	3.50	3.50
Carbohydrate, percent	4.78	4.78	4.80	4.80	4.71	4.71	4.73	4.73	4.60	4.54	4.63	4.58	4.58	4.33	4.23	4.23
Fat, percent	2.34	2.34	2.61	2.61	4.36	4.36	4.46	4.46	7.75	8.67	6.13	6.96	6.96	6.22	7.43	7.43

ANALYTICAL DATA
MILK HOMOGENIZED AT 185° F.

Pig No.	111	114	Normal 118	121	112	Homogenized 115	119	113	Corn oil 116	123
Weight when killed, kilos	19.53	21.71	20.70	18.78	19.02	19.15	17.71	19.43	18.09	17.54
Weight at start, kilos	4.99	5.67	5.90	5.90	4.99	4.54	5.90	5.22	5.22	4.99
Days fed	67	67	67	67	67	67	67	67	67	67
Average gain per day, grams ...	217	239	221	192	209	218	176	212	192	187
Composition of pig when killed:										
Dry matter, percent	34.09	34.21	30.44	33.81	30.12	33.37	28.58	30.90	29.33	28.35
Ash, percent	3.09	3.01	3.18	3.31	2.96	3.36	3.28	3.01	3.35	3.08
Protein, percent	13.49	13.59	14.31	13.44	14.25	14.88	14.44	14.31	13.88	13.69
Fat, percent	16.54	16.73	12.28	16.84	11.93	14.18	10.59	12.62	10.92	10.69
Ratio, protein to fat, 1:	1.23	1.23	0.86	1.25	0.84	0.95	0.73	0.88	0.79	0.78
Composition of pig when feeding began:										
Dry matter, percent	34.53	34.53	29.77	29.77	34.53	34.53	29.77	34.53	34.53	29.77
Ash, percent	4.08	4.08	4.06	4.06	4.08	4.08	4.06	4.08	4.08	4.06
Protein, percent	15.06	15.06	15.50	15.50	15.06	15.06	15.50	15.06	15.06	15.50
Fat, percent	14.85	14.85	9.59	9.59	14.85	14.85	9.59	14.85	14.85	9.59
Ratio, protein to fat, 1:	0.99	0.99	0.62	0.62	0.99	0.99	0.62	0.99	0.99	0.62
Food consumed, kilos	159.6	163.9	156.4	158.7	156.4	157.5	156.2	157.3	152.1	148.9
Composition of food:										
Dry matter, percent	16.03	16.03	16.01	16.04	13.81	13.81	13.82	13.74	13.58	13.08
Ash, percent	0.71	0.71	0.71	0.70	0.71	0.71	0.74	0.71	0.71	0.72
Protein, percent	3.60	3.60	3.60	3.60	3.61	3.61	3.61	3.54	3.53	3.62
Carbohydrate, percent	4.64	4.64	4.65	4.65	4.79	4.79	4.75	4.48	4.49	4.27
Fat, percent	7.08	7.08	7.05	7.09	4.70	4.70	4.72	5.01	4.85	4.47

ANALYTICAL DATA

DILUTION AND ENERGY

Pig No.	2.5% milk, undiluted			2.5% milk, undiluted			2.5% milk, undiluted			Skim milk		
	128	135	142	127	134	141	133	140	138	141	143	140
Weight when killed, kilos....	20.78	22.24	21.29	19.50	21.24	20.01	17.57	19.50				
Weight at start, kilos	9.08	9.65	9.25	10.16	9.76	10.10	8.34	9.36				
Days fed	51	51	51	51	51	51	51	51				
Average gain per day, grams	229	247	236	183	225	194	181	199				
Composition of pig when killed:												
Dry matter, percent	32.55	33.39	31.53	32.47	30.20	33.43	26.28	26.92				
Ash, percent	2.98	2.89	2.89	3.17	3.18	3.48	2.88	3.15				
Protein, percent	15.88	14.50	15.21	16.00	17.06	16.50	15.19	15.63				
Fat, percent	13.24	15.50	13.18	13.71	9.54	14.18	7.34	7.43				
Ratio, protein to fat, 1:	0.83	1.07	0.87	0.91	0.56	0.91	0.48	0.47				
Composition of pig when feeding began:												
Dry matter, percent	30.27	34.46	32.08	35.47	32.02	30.83	32.02	30.33				
Ash, percent	3.09	2.92	2.99	2.84	2.86	2.77	2.86	2.77				
Protein, percent	15.96	13.48	15.33	15.81	15.81	15.06	15.81	15.06				
Fat, percent	11.56	17.68	13.65	15.44	12.67	12.56	12.67	12.56				
Ratio, protein to fat, 1:	0.72	1.31	0.89	0.98	0.80	0.83	0.80	0.83				
Food consumed, kilos	155.5	158.2	158.2	178.2	178.0	178.0	165.7	165.9				
Composition of food:												
Dry matter, percent	12.08	12.08	12.08	9.08	9.08	9.08	9.79	9.79				
Ash, percent	0.76	0.76	0.76	0.58	0.58	0.58	0.76	0.76				
Protein, percent	3.79	3.79	3.79	3.01	3.01	3.01	3.97	3.97				
Carbohydrate, percent	4.89	4.89	4.89	3.60	3.60	3.60	5.03	5.03				
Fat, percent	2.63	2.63	2.63	1.89	1.89	1.89	0.03	0.03				

DISCARDS—SEE CLINICAL RECORDS

Pig number	7	8	9	10	11	12	13	14	15	16	18	19	20	21
Weight when killed, kilos	14.57	16.33	17.11	15.64	18.81	19.78	13.07	9.22	10.46	12.05	24.61	12.12	27.18	9.59
Weight at start, kilos	8.23	8.51	9.59	8.57	8.63	9.59	7.01	8.11	6.99	9.04	9.85	7.22	7.60	6.69
Days fed	39	39	39	39	39	39	32	38	56	32	94	32	94	32
Average gain per day, grams	163	213	193	181	261	261	190	29	62	94	157	153	208	91
Composition of pig when killed:														
Dry matter, percent	26.42	29.05	31.96	27.37	28.85	31.77	29.82	37.86	33.23	30.18	31.52	28.92	31.32	33.28
Ash, percent	3.29	3.10	3.07	3.55	3.12	2.81	3.34	4.69	4.58	4.13	4.16	3.49	4.48	3.43
Protein, percent	17.51	15.80	15.04	17.76	15.76	15.77	14.93	17.16	14.88	17.07	17.27	13.80	16.80	13.62
Fat, percent	5.00	9.60	13.34	5.42	9.33	12.42	11.07	15.68	13.61	8.44	9.71	11.12	9.51	15.98
Ratio, protein to fat, 1:	0.29	0.61	0.89	0.31	0.59	0.79	0.74	0.91	0.93	0.49	0.56	0.81	0.57	1.17
Composition of pig when feeding began:														
Dry matter, percent	34.41	34.41	34.41	34.41	34.41	34.41	32.16	32.16	32.16	32.16	32.16	32.04	32.04	32.04
Ash, percent	3.58	3.58	3.58	3.58	3.58	3.58	3.36	3.36	3.36	3.36	3.36	3.29	3.29	3.29
Protein, percent	16.60	16.60	16.60	16.60	16.60	16.60	15.50	15.50	15.50	15.50	15.50	14.13	14.13	14.13
Fat, percent	14.36	14.36	14.36	14.36	14.36	14.36	12.81	12.81	12.81	12.81	12.81	14.15	14.15	14.15
Ratio, protein to fat, 1:	0.87	0.87	0.87	0.87	0.87	0.87	0.83	0.83	0.83	0.83	0.83	1.00	1.00	1.00
Food consumed, kilos	187.1	146.5	114.3	175.6	136.0	116.8	80.6	71.8	130.1	109.4	551.6	70.0	498.8	54.0
Composition of food:														
Dry matter, percent	9.09	11.35	13.39	9.58	12.31	13.96	11.92	14.48	11.82	8.77	8.91	12.85	9.47	14.81
Ash, percent	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.75	0.70	0.70	0.70	0.70
Protein, percent	3.24	3.15	3.08	3.95	3.82	3.78	3.06	3.00	3.08	3.14	3.19	3.77	3.67	3.62
Carbohydrate, percent	5.10	5.07	5.03	4.90	4.91	4.79	4.95	4.92	4.93	4.84	4.99	5.14	5.08	5.15
Fat, percent	0.05	2.43	4.58	0.03	2.88	4.69	3.21	5.86	3.11	0.04	0.03	3.24	0.02	5.34

ANALYTICAL DATA

DISCARDS—SEE CLINICAL RECORDS

Pig number	22	23	24	26	28	29	30	31	32	33	46	62	120	122	126
Weight when killed, kilos.....	10.59	12.64	28.57	9.86	9.95	5.36	13.31	12.80	9.20	7.36	11.28	20.42	14.86	14.21	20.09
Weight at start, kilos.....	7.34	7.85	6.93	6.82	5.52	4.31	7.53	7.15	7.11	5.51	6.02	9.99	6.81	6.13	11.01
Days fed.....	32	32	94	45	29	29	29	29	29	29	38	61	67	67	51
Average gain per day, grams.....	102	150	230	68	153	36	199	195	72	64	138	171	120	121	178
Composition of pig when killed:															
Dry matter, percent.....	33.65	29.30	40.08	32.64	28.08	26.78	31.27	34.09	29.04	22.04	25.71	35.56	28.54	27.10	27.73
Ash, percent.....	3.73	3.35	3.73	3.92	3.87	4.53	2.79	3.47	3.39	3.33	2.88	3.14	3.59	3.50	3.10
Protein, percent.....	14.80	16.62	15.82	14.52	15.92	19.09	14.84	16.19	16.13	15.08	14.13	14.00	13.39	14.04	15.51
Fat, percent.....	14.76	8.78	20.40	13.61	7.56	2.31	13.23	14.01	9.09	2.60	8.20	17.73	11.24	8.59	8.02
Ratio, protein to fat, 1:.....	1.00	0.53	1.29	0.94	0.47	0.12	0.89	0.87	0.56	0.17	0.58	1.27	0.84	0.81	0.52
Composition of pig when feeding began:															
Dry matter, percent.....	32.04	32.04	32.04	32.04	25.58	25.58	25.58	25.58	25.58	25.58	30.37	34.33	29.77	29.77	35.47
Ash, percent.....	3.36	3.29	3.29	3.29	3.05	3.05	3.05	3.05	3.05	3.05	2.79	3.11	4.08	4.08	2.84
Protein, percent.....	15.50	14.13	14.13	14.13	15.25	15.25	15.25	15.25	15.25	15.25	14.19	13.88	15.50	15.50	15.81
Fat, percent.....	12.81	14.15	14.15	14.15	6.98	6.98	6.98	6.98	6.98	6.98	12.25	16.75	9.59	9.59	15.44
Ratio, protein to fat, 1:.....	0.83	1.00	1.00	1.00	0.46	0.46	0.46	0.46	0.46	0.46	0.86	1.21	0.62	0.62	0.98
Food consumed, kilos.....	62.2	97.6	344.5	68.1	152.7	127.5	93.4	119.6	65.2	91.0	179.1	203.1	153.4	146.9	178.2
Composition of food:															
Dry matter, percent.....	14.40	9.60	12.10	14.94	8.76	8.76	14.39	11.72	14.36	11.72	8.49	14.09	12.81	13.52	9.79
Ash, percent.....	0.70	0.75	0.70	0.70	0.87	0.87	0.87	0.91	0.87	0.91	0.65	0.88	0.73	0.72	0.76
Protein, percent.....	2.99	3.91	3.64	3.66	3.43	3.43	3.36	3.41	3.36	3.41	3.02	3.63	3.62	3.63	3.97
Carbohydrate, percent.....	4.90	4.92	5.12	5.13	4.40	4.40	4.32	4.40	4.29	4.40	4.73	4.80	4.50	4.75	5.01
Fat, percent.....	5.81	0.02	2.64	5.45	0.06	0.06	5.84	3.00	5.84	3.00	0.09	4.98	3.96	4.42	0.05

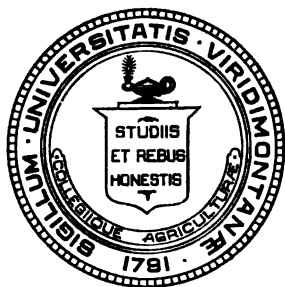
University of Vermont and State Agricultural College

Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

SOME STUDIES ON BORDEAUX MIXTURE

by B. F. LUTMAN



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BULLETIN 196: SOME STUDIES ON BORDEAUX MIXTURE

BY B. F. LUTMAN

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I. SUMMARY

1. When dilute solutions and weaker mixtures are used a material saving is made.

2. Thorough and violent stirring so breaks up the colloidal membranes formed in the mixture that they do not settle rapidly; but it will not entirely prevent settling.

3. Sphere crystals are formed in a short time from the copper salts in all of the ordinary mixtures. The covering power and adhesiveness of these bodies is very much less than that of the colloidal membranes.

4. Bordeaux mixture may be kept indefinitely, physically and chemically as when first made, by the addition either of a little cane sugar or of glucose.

5. Bordeaux mixture is fungicidal immediately upon its application.

6. The covering of a sprayed leaf consists of thin colloidal membranes composed of copper salts and of particles of lime.

7. The copper in the thinner membranes is immediately soluble and fungicidal; that in the portions adjacent to the lime particles gradually becomes soluble.

8. The lime particles are fungicidal.

9. When spores fall on a moistened leaf sprayed with bordeaux they are either: (a) killed, (b) their germination is retarded, or (c) they put forth a short germ-tube which is not likely to grow.

10. Bordeaux mixture kills largely by contact. The drip water is not highly fungicidal.

11. Bordeaux mixture under field conditions increases transpiration in the freshly sprayed plants.

12. Bordeaux mixture increases the size of the cells and of the chromatophores and nuclei of the sprayed leaves.

13. Bordeaux mixture increases the yield from potato plants by the prevention of tip-burn and flea beetle injury.

14. When plants which are not troubled by tip-burn or flea beetle are sprayed, yields are not increased.

15. At least two-thirds of the injury to late potato varieties other than that wrought by fungus or bacterial attack is due to tip-burn. The residue of the injury is due to the flea beetle.

16. In the greenhouse or in climates where neither tip-burn nor flea beetle are a factor in potato growing, or where neither early nor late blights occur, bordeaux mixture seems in the long run to be neither beneficial nor harmful, but quite unnecessary.

II. INTRODUCTION

The following studies on bordeaux mixture in its fungicidal and physiological relations are preceded by a brief statement of its chemical and physical properties, since a clear understanding of these facts is necessary if correct conclusions are to be drawn as to the changes induced in fungi or on the sprayed plants. Many students of bordeaux usage have disregarded the physical properties entirely, an omission so fatal that it is not too much to say that their work has no solid foundation. The writer does not claim to understand the chemistry of the mixture as it is ordinarily made, but in this respect he is not in a much worse condition than the chemists themselves. The entire physiological problem is a complex one and, as will be pointed out, it is not the same in different climates. However, the conclusions that are presented here seem to be true for Vermont.

III. PHYSICAL AND CHEMICAL PROPERTIES

The chemical nature of the compound or compounds formed when solutions of copper sulphate and calcium hydroxid are brought together is so complex and varying that it is possible only for a chemist to discuss the matter properly. The earlier view that only one compound, copper hydroxid, was formed and that this was the principal fungicidal constituent, has been replaced by the later one that as a result of the reaction, a basic copper sulphate, and probably a series of basic copper sulphates, is precipitated. Pickering (34), who has studied this series carefully, has found that different substances are formed if the ratio of the lime and copper sulphate solutions is changed. He used apparently only combinations of copper sulphate solutions and clear lime water to obtain six basic sulphates, enumerated by him as follows:—

- "A. $4 \text{ CuO}, \text{SO}_4$ (or $10 \text{ CuO}, 2.5 \text{ SO}_4$).
- B. $5 \text{ CuO}, \text{SO}_4$ (or $10 \text{ CuO}, 2 \text{ SO}_4$).
- C. $10 \text{ CuO}, \text{SO}_4$.
- D. $10 \text{ CuO}, \text{SO}_4, \text{CaO}$.
- E. $\text{CuO}, 2 \text{ CaO}$ (or $10 \text{ CuO}, 20 \text{ CaO}$) existence doubtful.
- F. $\text{CuO}, 3 \text{ CaO}$ (or $10 \text{ CuO}, 30 \text{ CaO}$)."

If he succeeded in doing anything with the chemical analysis of the ordinary mixture made with milk of lime, undoubtedly he would have found many more. The fact that he does not give such an an-

alysis is evidence of the difficulties in the way of determining resultants. The only thing that can be said is that the combinations must be numerous, very complex and probably varying in composition. The compound that is formed is of a colloidal nature, membranous in character, and apparently is not much heavier than the liquid in which it floats. The shape of these membranes, when isolated and dried to a slide, is shown in figure 1. These colloidal membranes, whatever their chemical composition, be it simple or complex, formed chemically in the matter above indicated, constitute the essential and valuable feature of the mixture. They float suspended in a strong solution of calcium hydroxid and calcium sulphate, the only purpose of which seems to be to hold them apart and to dilute the suspension.

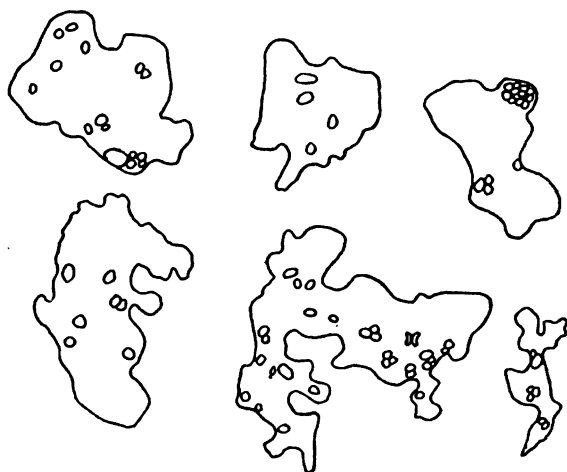


FIG. 1. Form of bordeaux membranes, showing particles of lime within.

The area of these membranes is a measure of the actual covering power of the mixture, as the author has shown in a previous article (29), and some combinations, such as that of Pickering's lime water and weak copper sulphate solution, the so-called Woburn bordeaux of England, while apparently containing a large amount of film do not in reality carry any considerable quantity. The method used in the measurement of these films was to dilute the mixture either 200 or 400 times; to spread half a cubic centimeter of this dilution on a glass slide and allow it to dry there; to remove the excess of lime and change the appearance of the copper by washing the slide with a weak solution of potassium ferricyanide acidified with a little acetic acid; to ascertain the area of the spot on the slide by means of a planimeter; to draw on paper a series of fields with the help of a camera lucida netz-micrometer

eye-piece; to determine the proportion of the area covered by the bordeaux films by measuring the area of the larger ones with a planimeter and by estimating that of the smaller; and, from the proportional amount covered by the film, the area of the half centimeter spot, and the dilution, to calculate the total amount of surface that the films produced in a certain mixture would cover. As far as it was possible, the conditions of preparation were made uniform throughout the trials. Several experimental mixtures were made and many samples measured in order to secure a representative average. The variable proportions of lime, especially under controlled conditions, and the difficulties experienced in pipetting so as to get a representative sample, are obvious.

The area covered by one cubic centimeter of the various mixtures tested was as follows:—

Pickering's bordeaux mixture (saturated lime-water) ..	70.6 sq. cm.
2½-2½-50 bordeaux mixture	111.8 sq. cm.
5-5-50 bordeaux mixture	257.0 sq. cm.
10-10-50 bordeaux mixture	393.6 sq. cm.
20-20-50 bordeaux mixture	498.8 sq. cm.
Lime 5, copper sulphate to neutrality	296.6 sq. cm.

As concentration increased so did the area of film become greater; but the increase was not proportional to that of the materials used. The inference to be drawn from this fact is that the colloidal films are thicker when more concentrated solutions are used, that they cannot be broken up as readily, thus wasting materials. On the other hand, the very dilute solutions, such as Pickering's, possess a greater covering power for the amount of materials used.

The particles of lime either left uncombined in the liquid or enclosed in the membranes play an important role in the fungicidal action of the mixture and also in the rapidity with which it settles. It is highly important that the precipitate should remain in suspension for as long a time as possible for the reason that often some hours elapse between the preparation of the mixture and its application. The changes in fungicidal properties induced by these particles will be discussed under the section on fungicidal action (page 15), but their relation to the rapid settling of the mixture properly may be discussed here.

The lime particles enclosed in the membranes add weight to the latter and cause them to sink more rapidly. The larger and heavier the weight inside the membrane the more rapidly it falls. Furthermore in its descent it carries with it or accelerates the fall of other and less heavily loaded membranes which may be in its way. The presence of lime particles not surrounded by this colloidal membrane may

be considered as doubtful, although they may occur. In some instances at least, the membrane is not much larger than is the lime particle and does not serve to buoy it up or appreciably to hinder its sinking. The path of such a lime fragment can be followed along the side of a glass vessel containing bordeaux. Not only does it fall rapidly but it also carries other lighter particles with it.

The effect of stirring the mixture on the rapidity of settling has been studied repeatedly. The most recent work on this point which has come to the writer's attention is that of Hawkins (21), who added dilute lime to dilute copper sulphate solution or vice versa and shook the resultant precipitate 5, 15, 25, or 35 times before placing the mixture in jars to measure the rate of its subsidence. He found that the way in which the components were mixed was not as important as was the subsequent stirring. No particular advantage was gained by pouring the two solutions together, as recommended by Galloway in 1896. In this connection it should be noted that the approved German method of combining the two is to pour the diluted copper sulphate solution into the diluted lime and to agitate the precipitate. Theoretically this is a correct procedure, for the films of copper sulphate then contain no lime particles to weight them down and send them to the bottom; but practically, all the copper sulphate solution is used up in the reaction and the films always enclose more or less lime water and lime particles. The Galloway method when carried out by hand is open to the objection that, as the lime and copper sulphate solutions are poured together over a strainer, the former always lags a few seconds behind the latter, and, as a consequence, there is always a heavy deposit of the larger bits of lime in the dregs which belatedly is added to the mixture after all the copper sulphate solution has been poured in and the reaction to a greater or less extent has taken place.

The stirring probably exerts several effects on the mixture, providing it is done vigorously.

1. The larger membranes containing considerable fragments of lime are broken open and the lime particles are released and sink while the lightened membranes remain in suspension.

2. The larger pieces of lime not enclosed within the membrane walls are kept from dragging down the lighter membranes.

3. The larger membranes are broken up, their surface area is increased, and thus their buoyancy is made greater per unit of weight.

If strong solutions of milk of lime and copper sulphate, such as occur in 10-10-50 or 20-20-50 bordeaux, are used, the resulting mem-

branes are too thick to be broken readily by any ordinary stirring. If, however, either of the solutions is used in a dilute form, the membranes are not resistant, as Hawkins (21) has shown, for the reason that subsequent vigorous agitation will break them up. Even the most rapid agitation will not serve the purpose if the two solutions are very concentrated, as is indicated by the results obtained at this Station as cited below.

1. Dilute solutions, such as are used for 5-5-50 bordeaux, were poured together in the usual way and stirred from 10 to 15 times.

2. Dilute solutions (5-5-50) were poured as usual, and the resulting mixture was beaten for five minutes with an ordinary rotary egg beater.

3. A dilute solution of copper sulphate was poured into a dilute solution of lime and stirred from 10 to 15 times.

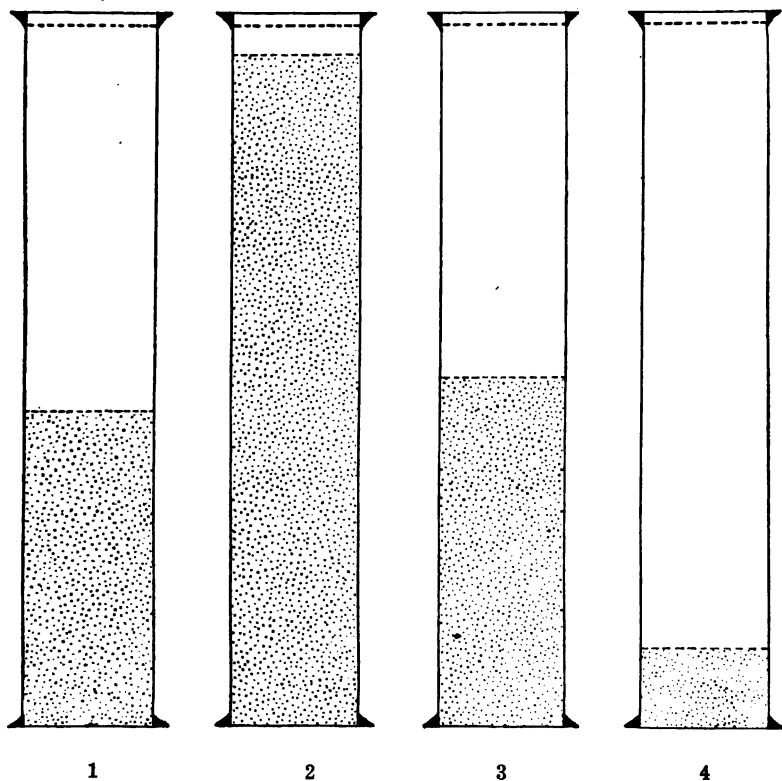


FIG. 2. Jars of bordeaux six hours after preparation. Previous treatment as follows: (1) 5-5-50 mixture stirred 10-15 times. (2) 5-5-50 mixture beaten for five minutes with an egg beater. (3) 5-5-50 solutions used, practically no stirring. (4) concentrated solutions, mixture beaten with egg beater.

4. Dilute copper sulphate and lime solutions were poured together but the mixture was stirred only enough to mix the two components.

5. Concentrated lime and copper sulphate solutions (one pound of either to the gallon) were poured together and the mixture beaten for five minutes with an egg beater.

The conditions relating to completeness of suspension after six hours are manifested in figure 2.

A study of the diagram clearly shows that even the violent stirring of the egg beater was not sufficient to make all the films buoyant. Practically all the precipitate in the dilute solution-egg beater trial was still in suspension after six hours, a remarkably satisfactory result.

Two facts of practical importance are to be deduced from these observations:—

1. The economy of using dilute materials.
2. The impossibility of so agitating a mixture made from concentrated lime and copper sulphate solutions as to prevent it from settling.

SETTLING AND AGING

When lime water or milk of lime and copper sulphate solution are mixed, a light blue precipitate is formed which, as has been shown on page 6, is composed of the precipitation membranes of one or more of the salts of copper. If this mixture is allowed to stand for a few hours the blue flakes begin to settle to the bottom leaving a supernatant clear liquid. This precipitation process continues if the vessel be left undisturbed for some hours until the blue solid occupies often less than a third of the space it formerly filled. The rapidity and extent of this settling process are dependent upon the dilution of the constituents used in making the mixture, the manner in which these were poured together, the thoroughness of the stirring and, perhaps, on other factors.

Aside from settling, the physical condition of the precipitate remains unaltered for some hours. It is still in the main a mass of films or membranes. If, however, a jar of the mixture is allowed to stand undisturbed for from 24 to 48 hours, it will be found to have changed its physical state radically and permanently. The precipitate still shows the same light blue color but, if examined under the microscope, it will be found that to a large extent the films have disappeared and that its hue is due to the presence of large numbers of blue spherical crystalline bodies (fig. 3, also plate I). Swingle (42) pointed out this fact, but its importance, indeed its very existence, does not seem to have be-

come appreciated generally, even by those who use bordeaux. Most bordeaux users throw away any mixture that has been left over night, believing apparently that it has spoiled chemically. Chemical changes may occur, but the important difference between a freshly made bordeaux and that which has stood for several days is physical in its char-

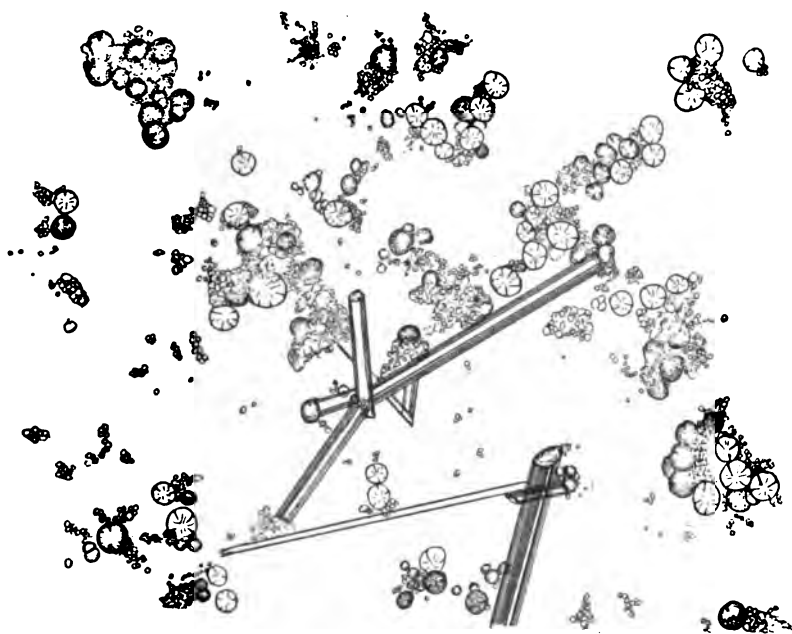


FIG. 3. Old bordeaux showing sphere crystals of the copper compound and long needle-like crystals of calcium sulphate.

acter; the copper compound or compounds have passed from a colloidal condition into a crystalline one. Furthermore, part of the calcium sulphate crystallizes in the form of long, slender needles that are frequently twinned. The precise form which calcium sulphate assumes when bordeaux is freshly made is unknown, but since it is only slightly soluble in water it must be in the form of a very fine precipitate, which either is amorphous or else too finely crystalline to be recognized under the microscope. The possibility remains also that the calcium sulphate is not formed at once but that it is the later product of some secondary reaction. At any rate it is present in an old bordeaux mixture in the form of the needle crystals. The excess of lime appears as small irregular granules.

The formation of these copper crystalline bodies in the precipitate evidently is due to an increased concentration of the copper salts at the

bottom of the vessel, as may be thus illustrated. If a hydrometer jar of bordeaux is left standing over night, the next morning it will be found usually that while the blue precipitation membranes on the surface of the blue layer have remained unchanged, there is an abundance of these copper spheres at the bottom. Intermediate stages in the

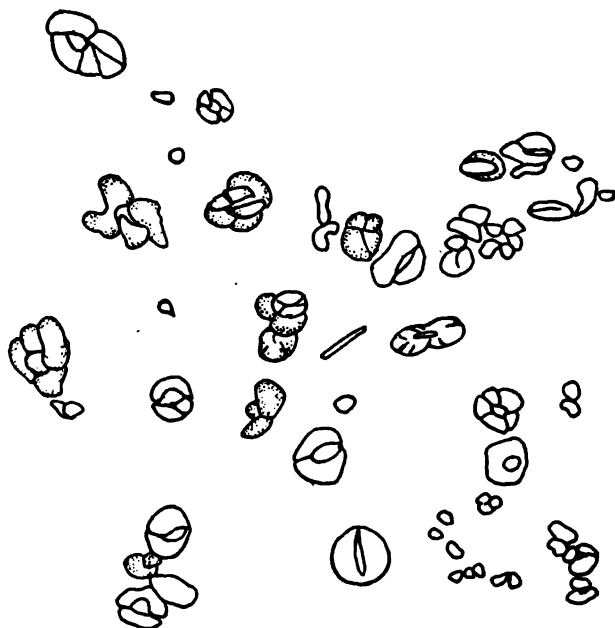


FIG. 4. Sphere crystals forming in old bordeaux; younger stages in their growth.

growth of these crystalline bodies may be found between the top and bottom of the precipitate. Although the earliest condition in which they can be recognized usually is to be seen while they are located within the old colloidal membrane, this does not occur always since they often seem to lie free. The growth apparently begins as a rule around one of the bits of lime, as the crystals show a clean center with two or three blue projections when they are first seen. Then the later growth fills in and rounds out this irregular body, making it appear approximately spherical (fig. 4). If, however, instead of pouring the mixture into a cylinder to remain undisturbed, the same quantity is spread out in a thin layer of not over a half inch depth, as in a large Petri dish, these crystalline bodies are not produced. A saturated solution seems to be a prerequisite if a physical rearrangement of the copper molecules is to occur.

The ultramicroscope has revealed the structure of the colloids to be similar to that of crystalline substances. Hence this transition to a crystalline state is quite conceivable, much more so than it would have been in the earlier days when colloids were believed to possess a structure resembling that of a sponge.

Butler (7) has given considerable study to the formation of these sphere crystals and finds that the rate at which they form depends also on the concentration and temperature of the mixtures. These crystalline bodies are not formed in Pickering's bordeaux even after continued standing. This may be due either to a lack of sufficient concentration in the precipitate or to the absence of lime particles around which the copper may crystallize readily. This property of the lime-water-bordeaux is a valuable one in field use, and Pickering has not emphasized it as strongly as he should.

IV. BORDEAUX POWDER AND PASTE

Manufacturers of bordeaux mixture sell it in the form either of powder or paste, usually combined with some insecticide such as arsenate of lead or paris green. Since many persons with but little spraying to do buy these mixtures, it may be well to point out their advantages and limitations.

Bordeaux powders are practically useless as a fungicide, because during the drying process the copper films are changed physically. Even when mixed again with water they do not regain their shape and covering properties. Their insecticide content is not injured in the drying process, which perhaps is fortunate since bordeaux powder is valuable only as an insecticide. Indeed, the finely divided bordeaux precipitate serves only to dilute the insecticide which, of course, costs an abnormally high price.

The reason why the value of bordeaux is impaired by drying is apparent. The colloidal films present in the freshly made mixture collapse and shrivel to such an extent that they possess none of the ability they had when fresh to apply themselves closely to and to dry to the surface of the leaves of sprayed plants. The process of drying completely changes the condition of these colloidal membranes; and the powder resulting from their desiccation is physically an entirely different substance.

Bordeaux paste costs very much more than does the same amount of bordeaux made at home; but if one has only a small plot of potatoes or but a few trees, its purchase may be advisable.

The commercial bordeaux paste mixtures on the market do not contain the copper spheres, at least none were found in the several samples examined. The process of their manufacture is not made public, neither does Pickering tell the method used by the firm preparing his mixture in a paste form. However, it is probably similar to that employed in the preparation of Pickering's bordeaux mixture, lime-water being used and the precipitate separated out by filtration. At any rate the precipitation membranes in their original condition are present in the paste as it is found on the market, and the mixture, after the addition of water, is physically the same as freshly prepared bordeaux and should be equally serviceable if not over-diluted.

V. PRESERVATION

The physical condition of a freshly made bordeaux mixture can be conserved by the use of sugar. Attention was called to this method by Kelhofer (23), although a German chemist named Rumm previously had taken out a patent on a mixture in the making of which the same chemical principles were involved. Kelhofer's recommendation was to add 100 grams of sugar to each hektoliter of the bordeaux mixture which it was desired to preserve. This is equivalent to 3.57 ounces to 10.57 quarts, or about four pounds to a barrel of fifty gallons. According to Kelhofer, the sugar and lime unite to form a lime saccharate and this latter compound further combines with the copper in a double chemical union. Kulisch (26) has found that by using this method bordeaux made in May could be kept all summer in as perfect condition as the fresh mixture, as shown by its efficiency in preventing the mildew of the grape. The small loss in adhesiveness brought about by the addition of the sugar is not of sufficient importance to be a serious practical deterrent to the use of this method of conservation.

Several trials made at this Station indicate that the amount of cane sugar recommended for use is unnecessarily large, at least for the 5-5-50 mixture so frequently used in this country. Not only is sugar expensive, but, also, it seems to act as a reducing agent if the mixture is kept any length of time. Glucose also serves as a preservative, but in a yet more pronounced way reduces copper.

Twelve quart jars were filled with freshly made 5-5-50 bordeaux mixture, to which were added either glucose or saccharose (cane sugar) in $\frac{1}{2}$, 1, 2, 3, or 5 gram lots, two of the jars being left unsweetened as checks. Noticeable reduction was evident after 48 hours in all the jars except the $1\frac{1}{2}$ grams saccharose and the $\frac{1}{2}$ gram glucose jars. The blue

precipitate appeared to retain its physical condition and an examination under the microscope showed none of the sphere crystals found in the old mixtures. The supernatant liquid in all of the jars to which the saccharose had been added was blue in color, due undoubtedly to the double lime saccharate in solution. This hue was most pronounced in the jars containing the five grams addition and hardly was noticeable in that containing one gram. Saccharose must exert some effect on the physical condition of the films, but it is difficult to determine its nature. Possibly the strength of the membranes is decreased, enabling them to expand more easily, thus inhibiting contraction and crystallization of the enclosed substances and of the membrane itself. Butler (7) claims that cupric oxide is formed after a long time, but the writer has observed no physical changes following the use of sugars.

The addition of a gram of sugar to a quart is equivalent to the use of about 200 grams to a barrel, or a little less than a half pound of sugar. The appearance of glass quart jars of bordeaux, three months after treatment, is shown in plate IV, fig. 1. The plate speaks for itself. Clearly it is now possible to make the spray material for an entire season once for all and to keep it in storage, or to preserve a barrel of the mixture if weather conditions become unfavorable for its use after it has been prepared. This is an important consideration in these days when copper sulphate costs fabulous prices. Furthermore, it is possible that even the present high price of sugar need not deter one and that the blacker grades of maple sugar might be used; but whether or not its impurities would affect injuriously the quality of the mixture, the writer cannot say.

VI. FUNGICIDAL EFFECTS

The earlier applications of this mixture were made entirely with a view of preventing fungus disease on the sprayed plants. The chance observation of Millardet in 1882 upon the grape foliage and fruit which had been sprinkled with a mixture of lime and copper sulphate in water in order to deter marauders from eating the ripe grapes, had far reaching consequences in the prevention of fungus attacks on cultivated plants. Millardet rightly attributed this prevention of disease largely to the action of the copper in solution in the mixture and the experiments under his direction (Millardet and Guyon, 31) were designed to determine the rapidity with which this copper became available under ordinary atmospheric conditions. As already described, freshly made mixture contains an excess of calcium hydroxid which must be neutral-

ized before the copper will pass into solution. It is obvious that this must be brought about either by the carbon dioxide of the air or by other gases which are acid when combined with water. This neutralization of the excess of lime is hastened by rain, dew, fog and damp air and is retarded by dry warm air. As their initial experiment was of great importance and has served as the basis for statements in many of the textbooks and bulletins dealing with the use of bordeaux mixture, and as it is not readily accessible, the original matter (translated) is quoted in full:—

“On April 10 the following types of the mixture were prepared :

	No. 1	No. 2	No. 3	No. 4	No. 5
Copper sulphate, grams	16	15	15	15	15
Pure lime, grams	3.36	3.36	6.72	13.44	26.88
Distilled water, liter	1	1	1	1	1

“As may be seen, in No. 1 there is one gram of copper sulphate in excess. No. 2 contains exactly the quantity of lime necessary to precipitate the copper sulphate. Tests made immediately after its preparation showed that there was no excess either of lime or copper sulphate. No. 3 contained twice as much lime as No. 2, while No. 4 contains twice as much as No. 3. Finally No. 5, which is the formula in common use, contains twice the quantity in No. 4. These five mixtures were dried at once in a desiccating oven at 36 degrees C.; then the products were pulverized in a mortar. Ten grams of each of the mixtures were spread in a thin layer between two Berzelius papers, supported below by a fine silk gauze, and were laid thus over five glass dializing jars having equal sized mouths. The necessary precautions were taken to prove whether the paper and the gauze were capable of absorbing any considerable amounts of copper.

“On the evening of April 12 the five jars were exposed in a garden in an open place. After April 13 they were watered simultaneously by all the rains that fell. When it did not rain for some little time, each jar was given an equal quantity of rain water, which had been collected in advance. Each dializer was placed separately in a funnel draining into a test tube in which any water poured on the apparatus finally collected. Every two or three days the water from each of the five apparatus was removed simultaneously and analyzed separately. The following shows the order of appearance of copper in the water which had drained through the mixture:

Mixture No. 1	April 17
Mixture No. 2	April 19
Mixture No. 3	April 24
Mixture No. 4	April 25
Mixture No. 5	April 30

"Other tests of the same nature, made by washing with rain water leaves of spindle wood and boxwood (*Buxus*) previously sprayed with these same five types of bordeaux mixture, gave analogous results. In general, the copper appeared in the water which had washed the leaves more quickly when the mixture contained less lime."

The conclusion drawn from this trial was to the effect that the copper in the mixture was not available until it had been exposed for a period varying from five to eighteen days.

CONCERNING THE SOLUBILITIES OF THE COPPER SALTS

These statements, although perhaps not the data on which they were based, seem to have remained unchallenged for a generation, notwithstanding the fact that they are opposed to the observations of everyone who has used the mixture. They mean simply that the mixture has no fungicidal properties until it has been largely washed off the foliage, while it is a well known fact in practice that bordeaux protects as soon as it is applied and that one of the best times to apply it is just before a rain, so that it may protect the leaves from the penetration of the fungus germ tubes.

Both Crandall (9) and Pickering (34) have shown that there was some error in Millardet's reasoning and that free copper is present almost immediately after spraying. Crandall repeated his experiments, spraying young apple trees in pots and collecting the drip from them in large stone jars. Tree 49, sprayed on August 23, may be taken as typical. A shower lasting twenty minutes came within twelve hours after the spraying, and the collected water contained 2.8 milligrams of soluble copper per liter. Determinations are as follows:

Date	Soluble constituents of drip waters				
	Amount of drip; liters	Copper		Alkalinity in terms of calcium oxid	
		Total milli-grams	Milli-grams per liter	Total milli-grams	Milli-grams per liter
August 24	1.64	4.6	2.8	45.1	27.5
August 27	13.92	74.4	5.3	154.8	11.1
September 3	1.25	104.4	83.5	Too dark	...
September 12	1.70	61.3	36.0	Too dark	...
September 20	1.80	9.8	5.4	Too dark	...
September 22	9.14	184.4	20.1	Too dark	...
September 26	0.80	41.0	51.2	Too dark	...
September 27	5.45	53.4	9.8	Too dark	...
September 29	10.60	238.8	22.5	Neutral	...
October 1	15.88	93.1	5.8	Neutral	...
October 6	3.02	72.4	24.0	Too dark	...

In the majority of cases the drip water was not collected until from five to seven days after the application had elapsed, but the conclusion reached by this investigator was that the copper was present constantly in solution in small but measurable quantities, varying from one part in 11,000 parts to one part in 170,000 parts. It is to be regretted that more drip water was not collected on the day following the spraying. Crandall further noted the slowness of the solubility of the copper deposited in the bordeaux. The amount of copper taken from a tree 75 days after spraying was more than that taken only seven days after, and the leaves still were coated. It must be noted here that the trees were given three heavy sprays with intervals between them only long enough to permit the applications to dry.

Pickering (34) agrees with Crandall, but seems to have made no experiments on the immediate solubility of the copper. He explains Millardet's and Guyon's failure to get free copper before five days as follows:—"In Millardet's and Guyon's experiments, the water supplied would form lime water so long as any free lime was there, and this would decompose any copper sulphate which might be liberated. But when bordeaux mixture is sprayed onto foliage it dries up, and the particles of basic sulphate and of lime will become separated from each other; hence, when the former are attacked by the carbon dioxide there may be no lime particles close enough to decompose the copper sulphate formed." He illustrates this point by wetting a piece of filter paper with a solution of potassium ferrocyanide, allowing it to dry, and then letting a drop of bordeaux fall on it. As long as the paper is wet from the bordeaux mixture no red color shows as the lime water can reach the copper compounds, but as soon as the drop is dry the red color appears in patches. Around the lime particles the paper is colorless. The same phenomenon can be demonstrated even better by drying a drop of bordeaux which is spread out thin on a glass slide, and then converting the copper by means of a potassium ferrocyanide solution. Practically the whole bordeaux film becomes red at once (fig. 8) even if the slide is not exposed to the air further than to dry the drop. The particles of lime may be seen imbedded in the film. The explanation goes back to the physical properties of the mixture. Each of the saccules formed when the copper sulphate solution and milk of lime come together is likely to contain some particles of lime, but the bulk of its contents is lime water. This evaporates and the small amount of residual calcium hydroxid is neutralized by the carbon dioxide of the air. These films in drying are very likely to overlap, but the

lime granules still lie some distance from each other. If this surface is now moistened, the water in contact with the film contains soluble copper, while that around the lime is strongly alkaline. In freshly applied bordeaux the copper in the thinner portions of the films and in those furthest removed from the lime particles possesses the strongest fungicidal value and enters into solution first, whereas in proportion as the applied mixture ages, more and more of the copper will be removed by rain and dew until only fragments of the original layer remain and, theoretically, these would be those located around the lime particles. As a matter of fact, however, these particles of lime, unless they are small, present more surface to the beating of the rain than the smaller film fragments and, consequently, are more likely to be torn from the leaf. This gradual solubility of the copper is one of the two outstanding features of the ordinary bordeaux mixture—the other feature is its adhesiveness; and while Pickering's claim for his bordeaux compound that its copper is much more soluble and immediately available than that in ordinary bordeaux is valid, it is also true that it will have lost its copper when the mixture made in the usual way is still on duty, giving off enough copper to prevent the growth or penetration of fungi.

The above discussion of the solubility of the copper salts in the mixture and of the physical and chemical form which the solution takes, has been introduced to show how useless has been much of the experimentation on the fungicidal action of the compound. Any experiments on the dilution of bordeaux mixture with water made with the view of testing its fungicidal or toxic properties in an aqueous solution practically are valueless (Dandeno, 11), as they do not reproduce in any detail the conditions that are found on a foliage leaf when a fungus spore and a layer of bordeaux mixture come together. The only thing such experimentation can show is the effect of a fairly alkaline medium on the spores or seedlings tried. The only method by which natural conditions can be reproduced is to dry dilutions of the mixture on slides and then to attempt to germinate the spores in a drop of water over this layer. If there is any soluble copper present or if the lime is still in excess, this will be shown by the water in this drop. In this way the chemical changes that occur in the films on slides are similar to those occurring in nature on the foliage of plants. If the bordeaux mixture is not dried to the slide but remains suspended in water, the lime contained in the films will continue to go into solution and the drop of the solution will remain alkaline and without free copper.

The method used in the work was as follows. Half a cubic centimeter of the required dilution was pipetted on the slide and spread out into a circular area of one-half to one square inch. After drying thoroughly, about the same amount of water was placed on the dried film and in this the spores were placed for germination. A very weak solution of dextrose was used in a few experiments but water was found to answer the purpose as well. A method somewhat similar to this has been used by Wallace, Blodgett and Hesler (44) in their study of the fungicidal value of lime-sulphur preparation, in which some of the dilution to be tested was sprayed over a slide, allowed to dry and the spores then sown in water over this layer. Barker and Gimingham (5) attempted to secure analogous results by passing carbon dioxide into the mixture. Such a procedure results only in neutralizing the alkalinity of the entire mass of bordeaux and is open to the same criticism which may be lodged against the attempt to determine the toxicity of bordeaux by the simple dilution of the mixture itself.

In the following experiments *Ustilago levis*, *U. nuda*, *Sclerotinia cinerea* and *Phytophthora omnivorum* were used at various times as the fungi with which to test the fungicidal properties of the mixtures. The *Ustilagos* and the *Phytophthora* are supposed to be fairly sensitive to copper solutions, judging by Wüthrich's (46) experiments on the same or similar species, in which he found that one part of copper sulphate in 8,000 entirely prevented germination. On the other hand, the great resistance of *S. cinerea* to copper salts is mentioned by Frank and Krüger (17), and other authors claim that a one percent solution of copper sulphate is necessary in order to prevent its growth.

EFFECT ON SPORE GERMINATION

1. *Effect of exposure of dried bordeaux mixture on its fungicidal action.* The following experiments will illustrate this effect:—

(a) 0.5 c.c. of a 1 to 100 dilution of 5-5-50 bordeaux was dried to a slide and left unexposed.

(b) Same as (a) but slide exposed over a damp night.

(c) Same as (a) but Pickering's bordeaux used instead of the 5-5-50; unexposed.

(d) Same as (c) but exposed.

The spores of *Phytophthora omnivorum* were sown in a little water on the slides and kept under a belljar over night. Tests (a) and (b) both showed fair germination of spores in the liquid with no differences visible as between the two, whereas in tests (c) and (d) prac-

tically no germination whatever occurred. The germination of the checks was excellent.

2. (a) 0.5 c. c. of a 1 to 100 dilution of 5-5-50 bordeaux was dried to a slide and left unexposed. *Phytophthora omnivorum* conidia were placed on it in water.

(b) Same as (a) but slide was exposed for three days, one of which was rainy, before it was brought in and the *P. omnivorum* conidia placed in the water on it.

(c) Same as (a) except that *S. cinerea* was used as the test fungus.

(d) Same as (b) but exposed for three days as in (c).

The conidia lying against the bordeaux in tests (a) and (c) were killed, and many of the floating conidia also were destroyed. No marked differences were observed as between (b) and (d), and no conidia showed germination. The germination of the checks was excellent.

3. (a) 0.5 c. c. each of 0.1 and 0.01 dilution of 5-5-50 bordeaux were dried to slides and exposed for two days. Rain occurred during all of one night, but otherwise the weather was clear.

(b) Same as (a) but unexposed. Spores of *Ustilago levis* and *Sclerotinia cinerea* were sown.

Slide	<i>Ustilago levis</i>	<i>Sclerotinia cinerea</i>
(a) 0.1, 5-5-50	No germination.	No germination.
(b) 0.1, 5-5-50	A few germinations of floating spores.	A few germinations of floating spores.
(a) 0.01, 5-5-50	No germination.	Good germination.
(b) 0.01, 5-5-50	A few germinations of floating spores.	Good germination.

Clearly there is very little difference in this respect between exposed and unexposed bordeaux. As shown in experiment 3 there may be a little free copper which was active but this would come almost within the range of variation of toleration of the spores to the poison.

4. *Effect of the water from bordeaux films on spore germination.*
As has been shown by Crandall (9) free copper always is present in the water which comes from the sprayed plants. It is very questionable if this has the slightest effect on fungus growth, as can be seen by the following experiments:—

Slides containing spores of *P. omnivorum* and *S. cinerea* were sown on:—

- (a) Supernatant water from exposed bordeaux.
- (b) Supernatant water, diluted ten times, from exposed bordeaux.
- (c) Control.

The germination was good in all of these trials. No difference could be observed either in number of germinations or in length of germ tubes.

Clearly the water derived from the bordeaux films has little germicidal power. Nearly all the soluble copper must lie close to the films from which it is derived, since when located at any distance it is neutralized by the calcium hydroxid originating in the lime particles. That the amount of fungicide available in a drop of water is not very large, with the exception of that in contact with the spray mixture, is further illustrated by the following experiment on lime-sulphur mixture:

5, *Effect of water from lime-sulphur spray on spore germination.*

Spores of *Sclerotinia cinerea* were sown on the following slides:—

- (a) Check.
- (b) 0.5 c. c. of 1 to 50, 1 to 100, or 1 to 200 dilutions of lime-sulphur dried to slide.
- (c) 0.5 c. c. of a 1 to 200 or a 1 to 400 dilution of 5-5-50 bordeaux, dried to slide.

No germination occurred in the lime-sulphur lot among the spores lying among the spray mixture, but there was some germination in the floating spores although the germ tubes were only one-half the length of those of the check.

No germination occurred among the spores resting on the bordeaux, but a few floating specimens put out short germ tubes. The spores were washed off into a weak solution of dextrose but practically no germination ensued, showing that the spores had been killed by contact with the fungicides.

Germination in the check was good, germ tubes being 10 to 15 times longer than the diameter of the spore.

6. *Germination of spores in contact with dried lime-sulphur mixture.* Spores of *Sclerotinia cinerea* were sown on slides on which 0.5 c. c. of a 1 to 1,000 and 1 to 10,000 dilution of common lime-sulphur had been dried in spots of about a surface area of a square inch. The spores on the 1 to 1,000 dilution did not germinate at all. Those on the 1 to 10,000 dilution produced short germ tubes, only about one-third as long as normal (figure 5).

7. *The effect of lime water and alkaline solution on spore germination.* Two lots of 5-5-50 bordeaux mixture were titrated with N/10 hydrochloric acid. It was found that about 0.36 c. c. of normal acid was required to neutralize the alkalinity of 1 cubic centimeter. Then milk of lime was made up so as to titrate about the same as the un-

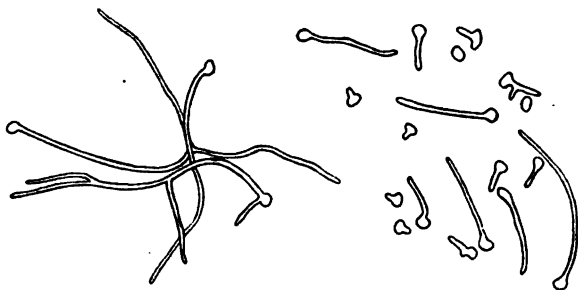


FIG. 5. Germ tubes of *S. cinerea* in nutrient solution and in nutrient solution in contact with dilute lime-sulphur mixture dried to the slide.

combined lime in 5-5-50 bordeaux mixture (0.35 c. c. N/1 acid per c. c.). Dilutions of 1 to 10, 1 to 100 and 1 to 1,000 then were made and the spores of *Sclerotinia cinerea* and *Phytophthora omnivorum* were placed in the drops, together with the addition of a very little dextrose solution, without allowing the latter to dry down on the slide. These slides were placed in a rack under a belljar together with a dish of concentrated potassium hydroxid solution to absorb the carbon dioxide. The following morning the spores in the check and in the 1 to 1,000 dilutions showed many germ tubes while the germination in the 1 to 100 dilutions was slight in the case of the *Phytophthora omnivorum* and in that of the *Sclerotinia cinerea* the tubes were very short, one to two times in length the diameter of the spores. In the 1 to 10 dilution there was no apparent germination, but the spores apparently were normal and had not been killed. In another trial the lime was used in 1 to 1, 1 to 2 and 1 to 10 dilutions. No germination occurred in any of them even after 24 hours. The lime water, and as much of the lime as possible, were drained off and the spores placed in a weak dextrose solution to which a few drops of lactic acid had been added. No germinations resulted. The contents of the spores were found to have become plasmolyzed, indicating that their long bath in the alkaline solution had killed them.

8. *Effect of distance of spots of the mixture on the germination.* Some slides were made up with lines of Pickering's bordeaux, just at

neutrality, while with others the mixture was put on in the form of checks (fig. 6). About two-thirds of the surface was covered in the checked slides and about one-third in the slides with lines. Pickering's

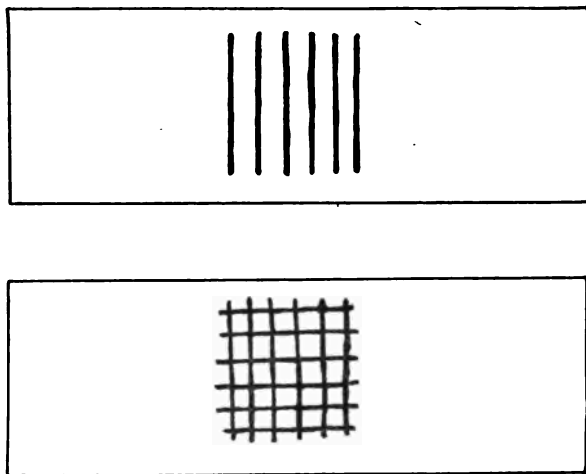


FIG. 6. Arrangement of bordeaux on slides.

soluble bordeaux was used so that the copper might be available immediately. The lines of bordeaux mixture were covered with plain agar and conidia of *Phytophthora omnivorum* sown on it. The slides then were placed over night in a saturated atmosphere. Not as large a percentage germinated on the finely checked as on the coarsely lined slides and the mycelium seemed to be less profuse. The same experiment was tried using *Sclerotinia cinerea* as the test fungus and similar results were attained. The germ tubes were a little shorter in the closely checked slides. The spores of *Sclerotinia cinerea* also were sown directly on the lines and checks of bordeaux in a very weak dextrose solution, but no germination resulted. The lines were about two millimeters apart. The following experiment will serve to show the cause of the lack of germination.

Bordeaux mixture (5-5-50 without dilution) and Pickering's bordeaux (concentrated precipitate at the bottom of the vessel) were placed on the slide in the form of dots, in some instances one being placed on a slide and in others two. The drop of liquid containing the spores was placed either between the two spots or at one side of the single spot. The results secured with the Pickering's bordeaux were most striking, as the following diagrammatic drawing will show:—

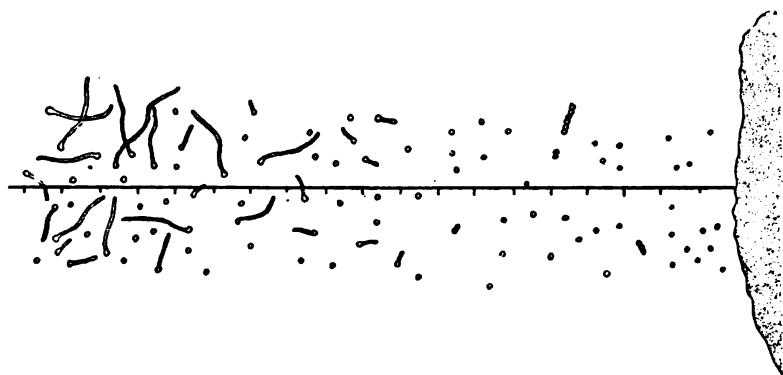


FIG. 7. Germination of *S. cinerea* near a drop of Pickering's bordeaux (diagrammatic). The regularly spaced marks on the horizontal line indicate tenths of millimetre from the drop.

The spores in close proximity to the spot apparently were dead and no germinations were visible. Part of those a little farther away put out germ tubes, but these were much shorter than those still farther removed from the influence of the copper. The distances indicated on the diagram are 0.1 of a millimeter. The results might be summarized as follows:—

0.8 to 1 m. m. from bordeaux spot. No germination.

1 to 1.5 m. m. from bordeaux spot. About 25 percent germination; tubes three to five times the diameter of the spore.

1.5 m. m. from bordeaux spot. About 50 to 75 percent of the spores germinated, the germ tubes being 20 to 30 times the diameter of the spore.

In similar experiments with 5-5-50 bordeaux the results were less clear cut than with Pickering's mixture. It was applied to the slide in the form of drops and lines. The great excess of lime complicated the action of the copper compounds. If the drop of water between the bordeaux spots covered them completely and dissolved some of the lime, the germination of the spores was prevented entirely, the result being due probably to alkalinity and concentration. If the drop of water touched the drops of bordeaux only slightly, the range of germination was about the same as in the spots of Pickering's mixture. Spore germination between lines and checks of the mixture was prevented, even when these were four to five millimeters apart. It was observed, however, that there were some germinations at one end of the spot of water at a distance of eight to nine millimeters from the nearest line of the mixture.

From these results the conclusion may be drawn that bordeaux protects the sprayed foliage not only over the immediate spot upon which it rests but over any unsprayed portions not more than a millimeter away.

The observations of Aderhold (1) to the effect that the spores of *Fusicladium dendriticum* germinate between freshly applied spots of bordeaux mixture on apple leaves is interesting, but he gives no information as to the distance between these spots. He believes, however, that the germination of the spores on sprayed leaves is no test of the efficiency of the bordeaux, but that its fungicidal effect is shown during the formation of the infection tube or during infection itself.

Observations were made also as to the position of the germ tubes with reference to the spots and as to the direction which later they assumed, in the hope of discovering either positive or negative chemotropic effect of the soluble copper. Neither the appearance nor the direction of the germ tubes was altered by the presence of the bordeaux spots.

9. *Effect of the presence of copper wire on germination of spores.* A series of cultures on glass slides was made of *Phytophthora omnivorum* and *Sclerotinia cinerea*, a quarter of a cubic centimeter of water being placed on each slide. Pieces of polished copper wire, gauze No. 32, one to five centimeters in length were placed in the various cultures. The five centimeter pieces of wire were rolled up into the form of a loose spiral about a centimeter across, and the two centimeter pieces were bent in the form of the letter U, while the one centimeter piece was put in the cultures straight.

The results, after 18 hours, were as follows:—

Five centimeter wire. *Phytophthora omnivorum* showed much abnormal germination while but very few spores developed normally.

Sclerotinia cinerea spores had not germinated among the coils of the wire nor at a distance of about twice the width of the wire away from it. The germinations near to the wire were with short tubes, while at some distance were as long as those in the control.

Two centimeter wire. *Phytophthora omnivorum* germinated in about the same manner as above; but a great number of the zoospores seemed to lie along the wire. Whether this was a chemotropic effect or due solely to physical forces was not determined.

Sclerotinia cinerea showed no germination within the U-shaped loop of the wire, but outside the germ tubes were at first shorter and, still further away, normal.

One centimeter wire. *Phytophthora omnivorum* spores were unaffected as to their germination.

S. cinerea germinated in much the same manner as cited above.

Apparently ordinary copper wire will inhibit germination in its immediate neighborhood and will prevent the formation of full length germ tubes at a slightly greater distance.

10. *Effect of copper wire and of bordeaux on Spirogyra.* *Spirogyra* is one of the algae most sensitive to the presence even of minute traces of free copper of any of the copper salts. It was thought, therefore, that the effect of bordeaux dried to slides on fungus spore germination could be checked with its action on a much more sensitive alga. A series of crystallizing dishes containing each about 100 cubic centimeters of water were used and in them were placed the following objects together with a little *Spirogyra*:—

1. Check.
2. 1 bordeaux slide; 1 to 200 cc. of 5-5-50.
3. 2 bordeaux slides; 1 to 200 cc. of 5-5-50.
4. 3 bordeaux slides; 1 to 200 cc. of 5-5-50.
5. No. 32 copper wire; 4 cm. long.
6. No. 32 copper wire; 8 cm. long.
7. No. 32 copper wire; 16 cm. long.
8. No. 32 copper wire; 32 cm. long.

These trials were started in the afternoon. The following morning, the alga in No. 8 was not quite as bright green as at the outset, and in three days it was brown and dead. A color change was manifested in No. 7 in three days. Numbers 5 and 6 showed a browning especially on the side next to the wire and the liquid was brownish, but the plants were not all killed. Numbers 2, 3, and 4 were not materially affected although the water was somewhat discolored and the plants on the underside were not as bright green as was the check. However, this appearance did not become at all noticeable until five days had elapsed.

The check remained normal throughout. The experiment was repeated with the following arrangement of the dishes, bordeaux slides and copper wire.

1. Check.
2. 2 slides; 1 to 200 cc. of 5-5-50.
3. 1 slide; 1 to 10 cc. of 5-5-50.
4. 2 slides; 5 cc. 5-5-50.
5. 1 to 200 cc. 5-5-50 spread over bottom of dish.
6. No. 32 copper wire; 4 cm. long.
7. No. 32 copper wire; 8 cm. long.
8. No. 32 copper wire; 16 cm. long.
9. No. 32 copper wire; 32 cm. long.

No. 8 was dead within 48 hours and No. 5 succumbed almost as promptly. Number 9 and 7 seemed to show much the same effect

but to a less degree, losing color on one side only and this after some days. The algae in No. 9 may have been originally in a somewhat healthier condition than their mates. The groups in Nos. 2, 3, and 4 showed the effects of the copper on the side lying against the bordeaux slides.

A similar experiment was tried on *Zygnema*, but the results were less satisfactory. This alga seemed to be much less sensitive to traces of free copper than *Spirogyra*. The crystallizing dishes were arranged in the following manner:—

1. Check.
2. 1 cc. of 1 to 100 cc. Pickering's bordeaux.
3. 1 cc. of 1 to 200 cc. Pickering's bordeaux.
4. 1 cc. of 1 to 1,000 cc. Pickering's bordeaux.
5. 1 cc. of 1 to 100 cc. 5-5-50 bordeaux.
6. 1 cc. of 1 to 200 cc. 5-5-50 bordeaux.
7. 1 cc. of 1 to 1,000 cc. 5-5-50 bordeaux.
8. No. 32 copper wire; 5 cm. long.
9. No. 32 copper wire; 10 cm. long.
10. No. 32 copper wire; 20 cm. long.

The bordeaux was spread over the bottom of the dishes and then allowed to dry, following which 25 cc. of water were poured into each dish and a small tuft of *Zygnema* added. The dishes were placed in diffused light. After 24 hours the check was still a bright green, except the side of the tuft turned towards the copper wire or the dried bordeaux. The 1 to 200 and 1 to 100 dilutions of Pickering's bordeaux affected the alga in about the same manner as the longer pieces of copper wire while the 1 to 100 and 1 to 200 dilutions of the 5-5-50 mixture turned it a much darker brown. The strongly alkaline properties of the latter mixture must be remembered.

A similar trial was made in which slides to which 0.5 cc. of 1 to 400 and 1 to 200 dilutions of 5-5-50 had been dried were compared with pieces of copper wire, 15 to 25 cubic centimeters in length. Part of these slides had been exposed for 48 hours in clear weather. The longer (25cm.) coils of wire affected the *Zygnema* more than either the 1 to 400 or 1 to 200 dilutions of the bordeaux, whether exposed or not.

GENERAL DISCUSSION

In the light of the result of the experimental trials thus far outlined, as well as those of Crandall (9) and Pickering (34), it is of interest to recall the suggestions made by Swingle (42) more than 20 years ago as to the method by which bordeaux mixture prevents fungal infection of plants. They were as follows:—

"(a). The spores may be prevented from germinating by inhibitory action. (b) The protoplasmic content of the spores may be killed outright in a short time before germination has commenced. (c) Through negative chemotropic action of the copper hydroxid the germ tube may be prevented from entering the plant. (d) The germ tube may be so weakened by copper in solution as to be unable to enter the host plant. (e) The germination tubes may be prevented from growing or be killed only on contact with solid particles of copper or its compounds, or with the cuticle or other parts of the host impregnated with copper. (f) The germ tube may be so much injured soon after germination as to cease growing before attempting to effect an entrance into the host plant, or may be killed outright soon after appearing. (g) The effects of the copper contained in bordeaux mixture may be exerted at a later stage of development of the fungi. (h) The presence of a thick coating of copper salts might impede the fruiting of a fungus already within the tissues of the host plant."

It may be worth while at this time and in the light of our knowledge of today to examine some of these possibilities in the order in which Swingle presents them.

(a) In a number of the experiments discussed in this bulletin the spores were prevented from germination; but whether this result was due to an inhibition of germination or to the death of the spores still is an open question. However, there is this much to be said, that in every case where the spores were washed off and placed in nutrient media they failed to germinate. A large proportion of the spores which might fall in the moisture on a leaf which is well sprayed with bordeaux would lie against the thinner membranes containing little lime and giving off small doses, increasing in concentration as the film itself is reached (figure 8), and as the spores lie in direct contact with this film they get the full benefit of any such solution. The border line between the inhibition of germination and the death of the spores probably is a narrow one and is dependent almost entirely upon the length of the time during which the spore remains in contact with the layer of fungicide. An exposure of only a few minutes probably is all that is necessary with the more sensitive fungi, varying with the fungicide used and with the completeness of covering it afforded the plant. In the experiments with the dots of bordeaux mixture (p. 24) the writer fails to find evidence that the soluble copper salts released exerted any chemotropic influence either positive or negative on the place of formation or the later direction of the germ tubes (fig. 6).

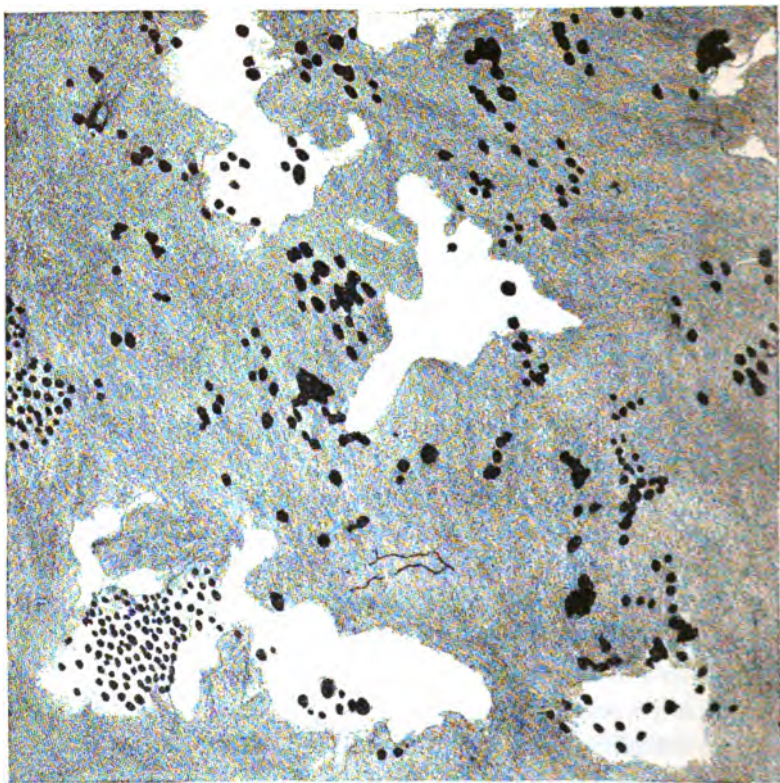


FIG. 8. Portion of slide covered with bordeaux. Lighter shaded portions show the copper reaction; dark bodies are particles of lime.

Swingle's suggestion, that the germ tube may be so weakened by the copper in solution that it may be prevented from entering the host plant, seems plausible in the light of the experiments now under review. Even in instances where the fungicide was not strong enough to kill the spores or to inhibit their germination, this was delayed and germ tubes were shortened. Either of these occurrences in most instances would be fatal; the plant thus produced would die, usually a result due to the evaporation of the drop of water in which it lay before it could germinate or could develop a tube of sufficient length to penetrate the epidermis of the host plant. It would seem from this that the absorption of very minute quantities of copper salts by the fungus serves to retard its growth process. In view of the fact that spore germination is brought about largely by the absorption of water and the swelling of the material already stored in the spore, the water containing traces of copper salts is partly inhibited by the plasma mem-

brane from entering the cell. This action must be still weaker than that assumed by Nägeli (32) as due to oligodynamic forces. Nägeli assumed that there were two types of poisoning, chemical and oligodynamic. The chemical type is brought about by the effects wrought by an appreciable amount of the toxic substance in solution. In copper sulphate this would mean for *Spirogyra* or for the ordinary fungi, one part in from 1,000 to 10,000 of water. If this solution is diluted still further so that there is only one part of copper sulphate in a million or more of water, the oligodynamic effect is manifested and results in no immediate death of cells but in a disorganization of the spiral bands of chlorophyll of *Spirogyra*. In the fungus cells no such visible internal disorganization can show how the poison is acting, but the retarded germination and short germ tubes make it apparent that the life processes in some way have been interfered with and are not progressing normally. This observation is confirmed by the growth on check slides.

(e) Swingle's fifth suggestion, that the germ tubes may be killed by growing against copper particles or against cell walls impregnated by copper, does not seem to be important. Such occurrences cannot be frequent. The germ tubes, if formed, hardly would grow in any great numbers within range of the sprayed spots, although a few might thus commit suicide. The presence of copper in the cuticle of sprayed plants has been demonstrated by Dévaux (12), who was able to show that copper was absorbed in sufficient amounts to be detected by means of the spectroscope. This means that the fungus in order to penetrate this cuticle must dissolve this copper-impregnated layer. If other enzymes act as does diastase, according to Ewert (15), the solution of this wall is made still more difficult and it may be almost impossible. The importance of this copper-impregnated cuticle in resisting the attacks of fungi after the bordeaux has been largely washed from the leaf, is apparent. That this protection does not continue throughout the season is unfortunate, for if it did one annual spraying would suffice. In this connection mention must be made of the suggestion of Rumm (35) that the leaves absorb the copper salts in the cuticle and that there it serves as a stimulus, due solely to its presence which influences the life activities of the plant. This author made a spectroscopic examination of the ashes of sprayed leaves from which all the external adhering copper had been washed and was unable to demonstrate the presence of copper. The assumption therefore was that the copper acted only chemotactically on the cells. The work of

Ewert (15) in this connection should be recalled, as he was able to show that copper salts were absorbed and by their action on the diastase affected the removal at night of the starch formed during the day. It is hardly possible that the plant cells could fail to absorb some of the copper, but on the other hand undoubtedly it would be in such dilution that it would have little effect on the fungi. The suggestion of Rumm above referred to, that the plant is made so healthy and vigorous by means of the copper salts that it can withstand fungus attacks, seems in view of the previous experiments to be much less plausible than the hypothesis which ascribes the benefit arising from spraying to the mechanical and chemical protection afforded to the plant externally by the presence of the layer of fungicide.

(f), (g), (h). No evidence has been presented in these trials bearing on Swingle's conclusions thus indicated. It is probable, if we are to judge by the results secured in experiment 8, page 24 and as has already been pointed out, that the presence of copper salts is more likely to retard germination and to inhibit the growth of the germ tube than it is to kill the tube after appearing, unless it should be so unfortunate as to grow towards a particle of the spray solution. The effect of the copper on the growth of the fungus after it has made its entrance into the host plant also must be very slight. If it is only present internally in sufficient quantities in some manner to stimulate the sprayed plant, it is hardly probable that it would be found to be of sufficient concentration there seriously to hinder the progress of the fungus throughout the leaf or stem. The external thick coat of spray mixture, however, would retard seriously the formation of new crops of spores on diseased leaves, especially in those diseases where the fruiting bodies are borne on the upper side of the leaf. For internal diseases, such as late blight of the potato and many of the mildews in which the conidiophores come to the exterior through the stomata, the presence of the fungicide largely on the under surface of the leaf would have small effect in preventing the spread of the disease in this manner.

These highly suggestive theories of Swingle, put forth at a time when little experimental evidence existed as to the method whereby the fungicidal effects of bordeaux mixture were exerted, have been shown by the experiments now under discussion and by those of Barker and Gimingham (4) in the main to be correct. However, the conclusions regarding the fungicidal methods of this mixture at which the

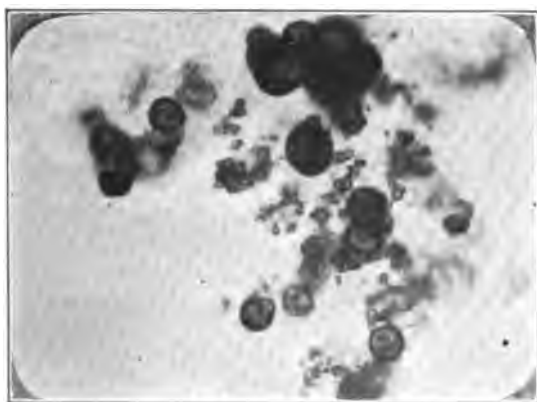


PLATE I. Figure 1. A drop of milk of lime in a solution of copper sulphate forms a gelatinous membrane around itself wherever the two come into contact. If the surface of this membrane is broken, new membranes are formed to cover the new points of contact. Inside these membranes are the lime-particles floating in a saturated solution of lime water.

Figures 2 and 3. Old bordeaux showing the sphere crystals and, in figure 3, the needle crystals, probably of calcium sulphate.



PLATE II. Sprayed and unsprayed rows of Green Mountain potatoes. August 28, 1911. The difference in appearance is due entirely to the destruction of the unsprayed rows by the tip-burn.



PLATE III. Sprayed and unsprayed Green Mountain potato plants, August, 1911.

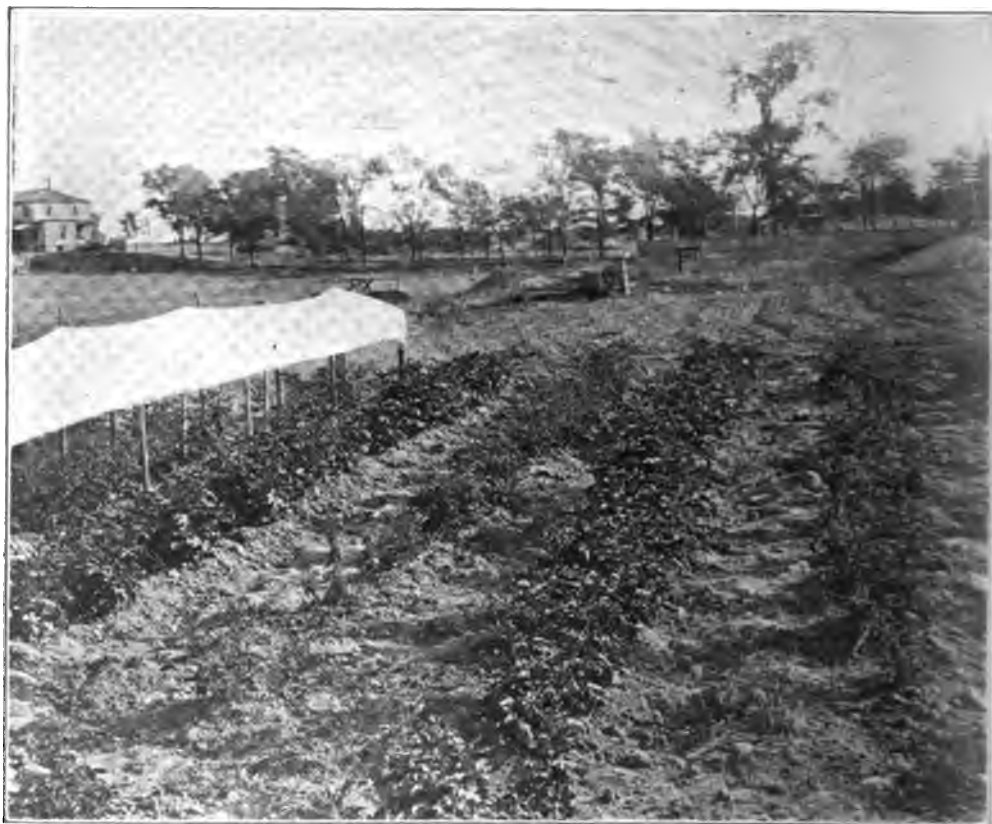


PLATE IV. Figure 1. Jars of bordeaux prepared in April; picture taken in July. No. 1 contained one gram saccharose (cane sugar); No. 2, two grams; No. 3, one gram glucose; No. 4 had had no addition of sugar.

Figure 2. Sprayed and unsprayed rows of Industrie. The German varieties of potatoes are affected even more seriously than the American by tip-burn.

writer has arrived are different in a number of details, some of which thus protected.

After a plant has been sprayed with any of the ordinary bordeaux mixtures, such as the 5-5-50 or 4-4-50 combinations, there is always present on the sprayed foliage a considerable excess of lime in the form of particles, but between these are located colloidal copper membranes giving off free copper as soon as they are moistened. If water falls on such a leaf in the form of drops in sufficient quantity to produce spore germination, the mass of the water is alkaline. This alkalinity is probably sufficient to prevent the germination of any of the ordinary fungus spores. If the water drains off the leaf and only a thin layer remains, that portion on the leaf surface between the lime particles—unless the latter are very close together—holds some soluble copper in it, while that in close proximity to the particles is strongly alkaline. If a fungus spore falls on this moistened leaf it will be killed if it falls in the portion covered by the bordeaux, while its growth will be inhibited and it may die from plasmolysis if it should be in the immediate vicinity of some of the lime particles. The leaf may not be entirely covered by the mixture, but if spores fall on it in the vicinity of the sprayed area one of three things may happen. If it is very near to such a spot it may be killed by the copper; if it is a little farther away, its germination may be inhibited; while if it is still farther away, its germination may be retarded and the germ tube may be shorter and probably not as vigorous as it normally would be owing to the absorption of traces of the poison. The distance the sprayed spots may be apart and still prevent the successful germination of the spores has been determined by the preceding experiments as at least a centimeter for some spores. It is not absolutely necessary therefore that every square centimeter of the leaf should be covered, although it is better if possible that it should be quite important.

The importance of the fungicidal properties of lime and the slow solubility of the copper salts formed in bordeaux mixture cannot be too strongly emphasized, for it is upon these two facts that the long continued efficacy of the ordinary mixture depends. The copper salts becoming slowly soluble over the larger part of the sprayed area serve to protect the larger parts of the foliage, but dotted throughout these dried films are the small particles of lime, the double function of which is to prevent too much of the copper salts in their immediate region from becoming too promptly soluble, and to prevent the germination of the spores and the growth of the fungi over the region in which

they lie. The claim is made for the Pickering bordeaux that since it contains no superfluous lime particles, it is fungicidal as soon as it is applied. It should be pointed out, however, as a corollary of this claim that this mixture must be, if valid, inherently defective in that it necessarily cannot remain fungicidal for nearly so long a time as the ordinary bordeaux, because its copper will have passed into a soluble condition and have been washed away by the rain at a time when the ordinary mixture with its excess of lime has some copper still entering into solution to protect the plant. The question seems to resolve itself as follows: the relative desirability of copper salts in considerable quantities immediately available for use and for a relatively short period of time, and of lesser quantities of these salts available at once but distributed over a longer time. Since the ordinary mixtures furnish enough free copper to exercise a fungicidal effect, there would seem to be no reason for shortening the life of an application of the mixture by spraying with a neutral bordeaux. If lasting fungicidal properties are desired, the ordinary bordeaux is better than the neutral bordeaux without lime particles; and for the immediate protection of the sprayed plant it is quite as good.

Another fact to be noted in this connection is that fungicidal preparations kill by contact. While the water coming from the sprayed leaves may show slight traces of copper, it never contains enough seriously to injure the fungus unless the latter is in intimate contact with the moistened sprayed surface. The amount of copper in solution must diminish rapidly in proportion as its distance away from the spray film increases; indeed at the surface of a drop of water its amount would be almost negligible, so far as its action on the fungi is concerned. It is possible that in some of its life processes the fungus spore may secrete soluble substance, for example carbon dioxid, in sufficient quantities close to the sprayed surface to bring about death in any case. Undoubtedly it is true that the fungus would give off carbon dioxid in its growth, but the instances where this would affect the penetration of the fungus are rare, since the great majority of the spores as they lie in water on the sprayed leaves would be likely to be killed or at least inhibited from germination.

The writer believes that the fungicidal action of ordinary bordeaux mixture may be expressed as follows:—

- 1 The fungus spores are killed by contact, either:
 - (a) with the bordeaux film, giving off free copper; or,

(b) with the alkaline solution derived from some of the lime particles.

2 The spores are inhibited from germination if they are in the region either of the bordeaux film or of the lime particles. The germination of the spores is retarded if they lie close to either of these substances and may be held back until the drop of water has dried up or a tube is formed which is too short and weak to penetrate the host cell walls.

VII. THE PHYSIOLOGICAL EFFECT OF BORDEAUX MIXTURE

1. SPRAYING TRIALS

On certain plants, such as the potato, the physiological effect of bordeaux mixture seems to be quite as important as is its fungicidal effect. The changes in the potato plant brought about in this manner have been noted particularly at the Vermont station and have been made at least half the basis for the plea it has made year after year, that potato growers spray regularly. The late blight is only serious enough in about half the seasons to make the application advisable on that account. Spraying in those seasons in which it does not occur would be lost labor were it not for the fact that a favorable physiological stimulus is exerted on the plant.

It will be understood clearly, of course, that this bulletin is not a discussion of experiments dealing with advisability of spraying for fungus diseases, such as late and early blight. This part of the potato spraying problem was settled long ago, and careful growers spray regularly. The present work deals entirely with the effect of the mixture on the potato plants themselves. The chance occurrence of fungus disease would have been most embarrassing, for it would have been difficult if not impossible to have arrived at conclusions touching the matter now under consideration which would have been beyond cavil. The writer was very fortunate in being able to carry on this work in years when both late and early blights were entirely absent. A better period could not have been selected, even if the weather could have been foretold five years in advance. Disease was a seriously disturbing factor only during one year (1915); and no extended experiments were at that time under way.

The discussion of these physiological changes in the potato plant is based in large part on the field work of the last four years. It is necessary at this point in the discussion to present the results of this field work. The theory that these good effects are due in large part

to climatic conditions was tested by a summer's spraying in Germany. Other phases of the subject were under observation during the same year and following years at Burlington. Furthermore, experiments were made in the garden and greenhouse to determine under controlled conditions the changes induced in the plants by the copper mixtures. The problem is an exceedingly complicated one and the literature is extensive. It has been thought best, therefore, to discuss previous work in connection with the experiments made at this Station rather than to attempt any complete resumé of the literature at the beginning of this section.

German potato growers rarely spray their potato crops for the reason that late blight has not been a serious trouble with them for a number of years and that they never have been able to secure as favorable physiological results from spraying as seem to have been obtained in this country. German farmers are among the most careful in the world; and it is quite safe to assume that if increased potato harvests followed regular spraying under German conditions they would spray.

In order to determine, if possible, the cause of this divergence between American and European results, the writer made a number of spraying trials in Germany during one season. The year was a fairly typical one, although the spring was rather late and cold. As in the case of the Burlington experiments, the writer was fortunate in hitting upon a year when no complications were introduced by late blight. The only changes which occurred in the plants were those wrought by the spraying.

SPRAYING POTATOES IN BURLINGTON IN 1912

Green Mountain potatoes were planted on sandy and clay loam soils in early June. One of the plots was a very light sand while the other was a heavy clay loam, especially at one end which extended across all the rows. The work was carried on under the direction of the then assistant plant pathologist, G. C. Cunningham. The physiological effect of bordeaux mixture on potatoes grown on a heavy clay soil was to be compared with its effect on the same crop grown on a light sand soil. The spring was very wet and late and the plants started slowly. On July 5, when the first spraying was attempted, they were only a few inches high. The same spray was used as in previous years, namely, a 5-5-50 bordeaux mixture plus a half a pound of paris green. Part of the plants were sprayed weekly while others were sprayed bi-weekly on the following dates:—

Sprayed weekly: July 5, 19, 26, August 2, 9, 16, 23, 30, September 6, 14.

Sprayed bi-weekly: July 20, August 2, 17, 30, September 14.

Tip-burn began to appear on the control plots about August 2 but was never as severe as in 1911. On August 30, the difference between the sprayed and unsprayed rows was very noticeable. No other disease prevailed.

Four harvests of the experimental potatoes were made on September 4-5, 18-19, October 2-4, and 30. The results, expressed in terms of a single plant, as well as in calculated bushels per acre, were as follows:—

Strength of spray	Sprayed	Tops lbs.	Large tubers lbs.	Small tubers lbs.	Total tubers lbs.	Large tubers bush.	Small tubers bush.	Total tubers bush.
First harvest; clay loam soil; September 4-5								
5-5-50	Wkly....	0.41	0.39	0.12	0.51	58.5	17.3	75.8
5-5-50	Bi-Wkly..	0.72	0.73	0.10	0.83	109.4	15.3	124.7
2½-2½-50	Wkly....	0.45	0.45	0.08	0.53	67.8	12.2	80.
Check	.....	0.52	0.42	0.09	0.51	63.6	13.5	77.1
First harvest; sandy loam soil; September 4-5								
5-5-50	Wkly....	0.98	0.99	0.10	1.09	148.5	14.3	162.8
5-5-50	Bi-Wkly..	0.56	0.68	0.11	0.79	102.	17.	119.
2½-2½-50	Wkly....	0.89	0.94	0.11	1.05	141.	15.9	156.9
Check	.....	0.43	0.55	0.10	0.65	82.5	14.4	96.9
Second harvest; clay loam soil; September 18-19								
5-5-50	Wkly....	0.88	1.16	0.15	1.31	174.	22.4	196.8
5-5-50	Bi-Wkly..	1.12	1.55	0.10	1.65	232.5	15.	247.5
2½-2½-50	Wkly....	0.88	1.11	0.15	1.26	166.5	21.8	188.3
Check	.....	0.61	0.75	0.11	0.86	112.5	16.8	129.3
Second harvest; sandy loam soil; September 18-19								
5-5-50	Wkly....	1.06	1.24	0.10	1.34	186.	14.7	200.7
5-5-50	Bi-Wkly..	1.27	1.81	0.10	1.91	271.5	15.3	286.8
2½-2½-50	Wkly....	1.21	1.57	0.11	1.68	235.5	16.8	252.3
Check	.....	0.79	1.17	0.12	1.29	175.5	17.3	192.8
Third harvest; clay loam soil; October 2-4								
5-5-50	Wkly....	0.67	2.29	0.14	2.43	343.5	21.6	365.1
5-5-50	Bi-Wkly..	0.78	1.90	0.11	2.01	285.	16.2	301.2
2½-2½-50	Wkly....	0.91	2.94	0.16	3.10	441.	23.5	464.5
Check	.....	0.38	1.34	0.13	1.47	201.	20.	221.
Third harvest; sandy loam soil; October 2-4								
5-5-50	Wkly....	0.62	1.80	0.15	1.95	270.	22.1	292.1
5-5-50	Bi-Wkly..	0.62	1.19	0.12	1.31	178.5	18.2	196.7
2½-2½-50	Wkly....	0.73	1.97	0.12	2.09	295.6	18.6	314.1
Check	.....	0.58	1.43	0.11	1.54	213.8	16.5	230.3
Fourth harvest; clay loam soil; October 30								
5-5-50	Wkly....Dead	2.34	0.23	2.57	351.	34.6	385.6	
5-5-50	Wkly....Dead	2.50	0.15	2.65	375.	22.5	397.5	
2½-2½-50	Bi-Wkly..Dead	2.39	0.17	2.56	358.	32.6	390.6	
Cop. iron sul.	Wkly..Dead	2.66	0.10	2.26	324.	15.5	339.5	
Check	Dead	1.97	0.16	2.13	295.5	24.3	319.8	
Fourth harvest; sandy loam soil; October 30								
5-5-50	Wkly....Dead	1.90	0.15	2.05	285.	23.	308.	
5-5-50	Bi-Wkly..Dead	...	...	...	...	...	...	
2½-2½-50	Wkly....Dead	1.88	0.12	2.00	282.	19.3	301.3	
Check	Dead	1.59	0.09	1.68	225.	13.2	238.2	

The check rows did not yield as many bushels as the average of the bordeauxed ones and the foliage is also slightly lighter in weight on them than it is on that from the sprayed plants. This increase of tubers and foliage of the sprayed plants is much more noticeable in the rows grown on the sandy loam. The same differences are discernible in the second and third harvests with a single exception; the tops of the control plants are lighter and the yield in tubers is less than is the case on the sprayed plots. The results secured at the fourth and final harvest seem to warrant the following statements as applicable to the 1912 experimental conditions.

1. Spraying with bordeaux mixture was equally well worth while on heavy clay loam and on sandy soils although somewhat better results were obtained on the latter type.

2. The amount of copper sulphate and lime used did not appear to be important, providing the mixture was fairly strong. A little difference appeared in favor of the 5-5-50 combination over the $2\frac{1}{2}$ - $2\frac{1}{2}$ -50.

3. Frequent and early sprayings did not seem favorably to affect the yield of tubers. Some of the plants were sprayed ten times; but they produced little or no larger crops than did those sprayed less often.

SPRAYING POTATOES AT BONN, GERMANY, 1912

During the summer of 1912, the writer had an opportunity to make spraying tests and observations on potatoes at Bonn, Germany. He desires at this point to express his appreciation of the courtesy of Professor Max Koernicke of the Poppelsdorf Agricultural Akademie, of Herr Böddinghaus of Bonn and of Herr Weinlich of Vilich. To Professor Koernicke especially are his hearty thanks due for efforts in his behalf.

This region of Germany, while not so well known as a potato growing country as is that around Berlin, produces this crop in great abundance, both in the Rhine valley itself and on the low foothills which lie along the western bank. The soil presents many variations within a small region, for that in the valley is sandy and light while that on the hills is more inclined to be a heavy loam or clay. It was with the intention of testing soil effects on spraying that the trials were made on land in these two localities.

The sprayings on the higher lands were made on the estate of Herr Otto Böddinghaus, the Melb Tal farm, about a mile from Bonn. Two

trials were made here; one on a small field of early potatoes, Paulsen's Julie, located near the Hof and the other on a larger field of late potatoes, Industrie, about a half mile from the Hof. The two varieties were those commonly planted in the country around Bonn and were recommended as being highly resistant to the leaf roll disease.

The land on either plot was a heavy clay loam admirably adapted to potato growing. The spraying operations in the valley of the Rhine were made on the farm of Herr Weinlich, Hof Lede, located near Vilich near Beul across the Rhine and about four miles distant from Bonn. The soil was as light and sandy as that around Burlington, but was considered excellent for potato culture. The variety planted was Industrie.

The spraying was done with a 5-5-50 bordeaux or with "Cucasa," applied by means of a knapsack spray pump, in sufficient quantities thoroughly to cover the foliage. The crops were planted in early April and were far enough advanced by the middle of June to begin the spraying. The applications were made on the following dates:—

Melb Tal farm; on Paulsen's Julie (early variety) June 15, July 1, July 16.

Melb Tal farm; on Industrie (late variety) June 15, July 1, July 16, Aug. 14.

Hof Lede farm; on Industrie (late variety) June 19, July 3, July 17, Aug. 20.

Two hundred plants on each of these plots were sprayed with bordeaux mixture, two hundred with "Cucasa," and two hundred were left as a control. "Cucasa" is a proprietary, clear blue, copper sulphate-calcium carbonate-cane sugar solution of German origin. Trials of this material were made at this Station in 1911, as set forth in bulletin 162. As there are no Colorado potato beetles in Germany, it was unnecessary to use arsenicals on the control rows. The plan of spraying, repeated twice on each of the three plots, provided for 54 plants each treated with bordeaux, two similar rows sprayed with Cucasa and two left untreated.

The early potatoes at the Melb Tal farm were harvested on August 15. At this time the foliage of the bordeauxed plants seemed still to be somewhat greener than that of the unsprayed, the estimate of green foliage for the former being 25-30 percent, for the latter, 10-15 percent. Unfortunately through a mistake two of the control rows were dug before August 15 and no record could be obtained of them. The first two rows sprayed with bordeaux were situated so near a tree that

the end of the rows were shaded after about four o'clock in the afternoon (see Von Oven's work, 33) and consequently the second two rows thus sprayed represent the conditions more fairly. The harvest of the late potatoes at the Melb Tal farm occurred on September 28. It was estimated that about 90 percent of the foliage was dead on the sprayed plants as compared with about 95 percent on the unsprayed. The stalks still were green but the foliage had been killed by a heavy frost about a week before. This early frost was unfortunate, in that it afforded the bordeauxed plants no lengthened season wherein to finish their work, while on the other hand it was fortunate in that it gave an opportunity to show any effect the mixture might have produced due to causes other than lengthened life. No disease of any sort appeared during the growing season; and the tubers were nearly free from scab.

The late potatoes at the Hof Lede farm in the Rhine valley were harvested on October 1. The plants were quite dead with the exception of a few green stems, these being most noticeable in the sprayed rows. The laboratory helper had visited the field about two weeks before this date, before the plants had been affected by the frost, and reported that at that time the sprayed rows still displayed foliage enough readily to distinguish them from the unsprayed areas. The yield here was less than on the Melb Tal plots, but the tubers were large and clean. No disease had appeared in the fields during the growing season.

The following table exhibits the yields, two rows of fifty plants each being harvested in each case. The first two harvests were made on Melb Tal farm on August 15 and September 28, the latter on Hof Lede farm on Oct. 1.

	Paulsen's Julie			Industrie			Industrie		
	Large tubers lbs.	Small tubers lbs.	Total yield lbs.	Large tubers lbs.	Small tubers lbs.	Total yield lbs.	Large tubers lbs.	Small tubers lbs.	Total yield lbs.
Bordeaux ...	136.5	15.5	152.	207.	10.5	217.5	69.	15.5	84.5
"Cucasa"	158.7	19.5	178.2	202.7	10.	212.7	85.5	16.	101.5
Check	178.	16.	194.	192.	15.	207.	81.	17.	98.
Bordeaux ...	159.5	14.8	174.3	187.	9.	196.	78.	18.	96.
"Cucasa"	157.7	17.6	175.3	192.	7.2	199.2	71.	17.	88.
Check .....	....	....	....	190.5	7.8	198.3	71.	21.	92.
Bordeaux ...	296.	30.3	326.3	394.	19.5	413.5	147.	33.5	180.5
"Cucasa" ...	316.4	37.1	353.5	394.7	17.2	411.9	156.5	33.	189.5
Check .....	....	....	369.3	382.5	22.8	405.3	152.	38.	190.

In addition to these field trials, a small experiment on potatoes and beans was conducted in the Economic Botanical Garden of the Institute. The potatoes of the Industrie variety, like those in the field, showed no effect which properly may be said to be due to the spraying:

and similar results were secured with the beans. These potatoes were sprayed four times, June 15, June 26, July 16, and August 20. They were harvested on October 7.

	Large tubers	Small tubers	Total tubers	Total tubers per plant
Control, 38 plants	76.5 pounds	13 pounds	89.5 pounds	2.36 pounds
Bordeaux, 37 plants	84. pounds	11 pounds	95. pounds	2.56 pounds

The general results of these experiments indicate that under German climatic conditions spraying either potatoes or beans has little effect upon the plants or upon their yields. The observed differences are too slight to be of consequence in field experimentation and doubtless are due to variations in soil and individual plants. The marked increase obtained under conditions prevailing in America is conspicuous by its absence. Favorable results might have been obtained had the heavy frost of late September held off; but this is very problematical. There certainly would have been no very marked increase in the yield of the sprayed over the unsprayed plants, as they were all in nearly the same stage of maturity. Slightly favorable effects could be observed on the sprayed plants grown on the light sandy soil in the Rhine valley, while on the heavier soils of the foot hills the sprayed and unsprayed plants seemed to be about alike. At any rate it is safe to say that if there were any favorable results brought about by the spraying procedure they were due to the lengthened life of the sprayed plants and not to any stimulus carried by the action of the copper in the mixture.

It should be noted here that the truth or falsity of the doctrine of the stimulating effect of bordeaux mixture on the foliage of the potato plant can be better determined in Europe than in America. The Colorado beetle is not a pest, and one can study the question without having to deal with the possible complications which the insecticides applied for its control may introduce.

That spraying potatoes with bordeaux mixture is not a profitable farm procedure in Germany is evidenced by the fact that few of the growers practice spraying. During recent years there has been an almost complete absence of late blight; and there seems to be lacking also to an unusual degree any evidence indicating that the favorable physiological effects often obtained from the use of bordeaux under American conditions are a factor in Germany.

SPRAYING POTATOES IN 1913 AT BURLINGTON

The summer of 1913 was as favorable a season as the preceding four years had been for field experiments on the physiological effect of bordeaux mixture on potatoes, the plants being entirely free from *Phytophthora* and *Alternaria* blights. However, the potato beetle and flea beetle were abundant and were very difficult to control. Some of the seed potatoes were very late in arriving at Burlington so that they could not be planted before June 6. This shortened the growing season by at least two weeks and considerably reduced the yields. Green Mountain and Early Rose were used for purposes of comparison with the two German varieties, Industrie and Paulsen's Julie, that had been used the preceding year in the experiments made at Bonn, Germany. The two American varieties were from New York state seed, and the German seed tubers were obtained from Haage & Schmidt through the courtesy of Dr. W. A. Orton of the Bureau of Plant Industry of the United States Department of Agriculture. The three varieties, Green Mountain, Early Rose and Industrie, were sprayed with 5-5-50 bordeaux, about a pound and a half of dry arsenate of lead being added as an insecticide to every fifty gallons. The control plots were sprayed with arsenate of lead and water and occasionally dusted with paris green and lime.

	Pounds per plant			Bushels per acre		
	Large tubers	Small tubers	Total yield	Large tubers	Small tubers	Total yield
<i>Green Mountain,</i>						
Sprayed	1.54	0.23	1.77	231.6	32.7	264.3
Check	1.41	0.14	1.55	211.3	20.7	232.5
<i>Early Rose,</i>						
Sprayed	1.48	0.19	1.67	221.	28.	249.
Check	1.19	0.16	1.35	178.5	24.	202.5
<i>Industrie,</i>						
Sprayed	0.09	0.54	0.63	13.7	80.9	94.6
Check	0.05	0.63	0.68	7.4	94.6	102.

The above figures show that, notwithstanding the late planting, the yield of the American varieties was increased as a result of spraying operations. This difference undoubtedly would have been much greater if the plants had remained green as is usually the case into October. The apparent small decrease on the German variety, Industrie, hardly can be considered as conclusive as only three rows were used, the middle row serving as a check on the two sprayed rows. In an experiment in another part of the field on the German varieties the results were as follows:—

Industrie		Paulsen's Julie	
Sprayed, pounds per plant	Unsprayed, pounds per plant	Sprayed, pounds per plant	Unsprayed, pounds per plant
1.19	1.09	1.29	.96

The difference in Industrie is slightly in favor of the sprayed rows while it is still more favorable in the case of the early variety, Paulsen's Julie, and it seems safe to say that if the latter had been planted at the proper time, it would have shown a much larger gain. The results on the variety Industrie are to be regarded as inconclusive and the tests were repeated in 1914. The small yield secured from these German varieties is further indicative that they are adapted to a longer growing season than that found in this latitude.

Further trials were conducted on another field of Green Mountain potatoes in which the check rows were sprayed twice and dusted twice with arsenate of lead alone, whereas the other plants were sprayed with various strengths of bordeaux:—5-5-50, $2\frac{1}{2}$ - $2\frac{1}{2}$ -50 and $1\frac{1}{4}$ - $1\frac{1}{4}$ -50. Even though the greatest of care was used, the flea beetles did more damage to the foliage of the check plots than to that of the sprayed ones. The plots were sprayed July 12, July 22, August 7 and August 21. A fifth spraying would have been made during the following month, but on September 12 a heavy frost killed the plants.

Green Mountain	Pounds per plant			Bushels per acre		
	Large tubers	Small tubers	Total yield	Large tubers	Small tubers	Total yield
$1\frac{1}{4}$ - $1\frac{1}{4}$ -50	2.03	0.09	2.12	304.	13.5	317.5
$2\frac{1}{2}$ - $2\frac{1}{2}$ -50	2.17	0.06	2.23	325.4	8.5	333.9
5-5-50	2.18	0.08	2.26	326.2	12.1	338.5
Check	1.53	0.15	1.68	229.5	22.	251.5

SPRAYING POTATOES IN 1914

Two objects were kept in mind in the experiments conducted during the summer of 1914:—(1) to repeat the trials of the effect of sprays on the German varieties of potatoes used during 1912 and 1913, and (2) to determine as far as possible the effect of the bordeaux mixture on a number both of early and late American varieties. The land chosen for this work was very unsuitable in view of the season, for the soil was quite light and sandy. It was the same plot that had been used during the summer of 1909; but the rainfall during that season was not only greater but it was better distributed than during 1914. A supplementary experiment was conducted on an adjacent piece of land, mostly a heavier soil, which yielded somewhat better results. The crop was planted on May 20. A long spell of dry weather then intervened

which prevented much growth during late May and most of June. The first appreciable rain fell June 19. It is doubtful if any germination occurred during these 30 days, since the temperature continued above normal and the soil was like dry sand. Indeed many of the smaller cuttings dried up and never germinated. Others apparently were infected by the *Fusarium* fungus and, during August, developed the *Fusarium* wilt. In all, hardly half a stand of normal plants was obtained. The wilt disease was largely confined to an early variety known as the Luther Putnam, bought in the market in Burlington. The results from most of the plots planted with this variety were discarded as being unreliable. Scattering plants affected by the same malady were found in other plots, but as it was felt that the final result would not be influenced materially by this fact, only the badly affected specimens were removed.

PLAN OF POTATO SPRAYING 1914

Variety	Number of rows	Number of plants	Sprayed or unsprayed	Weight of salable tubers	Weight of small tubers	Total weight of tubers
Green Mountain	_____	37	Unsprayed	61.6	3.8	65.4
	_____	52	Sprayed	79.5	7.4	86.9
Luther Putnam	_____	62	Unsprayed	52.6	8.2	60.8
	_____	64	Sprayed	62.1	7.2	69.3
Industrie	_____	26	Unsprayed	15.5	9.7	25.2
	_____	21	Sprayed	20.9	7.4	28.3
Paulsen's Julie	_____	53	Unsprayed	40.7	13.8	54.5
	_____	53	Sprayed	41.	16.	57.
Early Rose	_____	56	Unsprayed	43.6	6.	49.6
	_____	60	Sprayed	54.4	6.6	61.
Green Mountain	_____	61	Unsprayed	63.5	11.2	74.7
	_____	70	Sprayed	86.2	10.4	96.6

Luther Putnam	{		Unsprayed				
			Not used (too much Fusarium wilt).				
	{		Sprayed				
Industrie	{		59	Unsprayed	26.3	18.3	44.6
	{		45	Sprayed	38.8	13.5	52.3
Paulsen's Julie	{		58	Unsprayed	27.7	16.3	41.
	{		60	Sprayed	36.6	15.	51.6
Green Mountain	{		74	Unsprayed	54.4	9.2	63.6
	{		70	Sprayed	73.3	4.7	78.
Paulsen's Julie	{		50	Unsprayed	15.3	12.5	27.8
	{		48	Sprayed	33.1	14.	46.1
Green Mountain	{		67	Unsprayed	57.	8.6	65.6
	{		71	Sprayed	69.2	13.6	82.8
Luther Putnam	{		Unsprayed				
			Not used (too much Fusarium wilt).				
	{		Sprayed				
Green Mountain	{		119	Unsprayed	71.1	14.	85.1
	{		119	Sprayed	77.4	17.1	94.5
Green Mountain	{		75	Unsprayed	68.5	9.6	78.1
	{		84	Sprayed	84.8	13.3	98.1
Green Mountain	{		96	Unsprayed	92.6	18.7	111.3
	{		107	Sprayed	122.3	22.1	144.4

Great difficulty always has been experienced in obtaining adjacent plots of land in the vicinity of Burlington with soil nearly enough alike to make the results obtained from them comparable. Soils located only a few yards apart often are radically different. In order to minimize as much as possible the effect of this variant, the sprayed

and unsprayed rows were alternated and, as a rule, the varieties were planted in several portions of the field. The sub-joined plan shows this alternation but in a condensed form. All the plots were four rows wide, the two middle rows being sprayed, while the two outer ones were left unsprayed. This plan paralleled sprayed and unsprayed rows, thus facilitating the work. No space existed between the plots other than that between the rows.

The plots were sprayed on July 14, July 25, August 7, August 22 and September 12, using 5-5-50 bordeaux to which 1.5 pounds of dry arsenate of lead had been added. The control rows were sprayed with an arsenate of lead solution. Some of the plants had to be dusted occasionally with paris green and lime because the arsenate of lead did not at all times sufficiently repress the numerous Colorado beetles.

Observations were made occasionally on the progress of tip-burn. The delayed germination seemed to retard the onset of this ever present malady. Its effect was not marked before late August or early September, although the early varieties such as the Putnam, Early Rose and Paulsen's Julie were attacked in mid-summer.

It should be remarked, however, that the presence of the wilt disease on some of the plants made accurate estimation difficult. Not over five percent of the leaves of the Green Mountain plants were tip-burned by August 15. This observation seems to indicate that tip-burn is a disease which is more likely to appear at certain stages in the maturity of the plant, when the tubers have attained a size large enough to serve as a drain on the energies of the plant on which they are growing, than a malady which occurs at a definite date. At no time during the summer did the late potatoes on the experimental plots suffer as much from tip-burn as they did during preceding seasons. On adjacent supplementary plots, largely Green Mountain with a few Early Rose, tip-burn appeared at a much earlier date and was much more severe. They were located partly on very low ground, a heavy clay loam, and partly on higher ground with a very light sandy soil, similar to that on which the experiment plots were placed. The difference in the amount and appearance of tip-burn on the two ends of the rows was as marked as the difference in the soils. The succulent plants on the damp soil were yellowed and showed an unhealthy condition and incipient tip-burn on July 25, although but little of the disease then actually was present. The plants growing on the higher ground were normal at this time, both as to the appearance of the foliage and the

absence of tip-burn, although their leaves were thinner and less succulent and their stalks formed a looser growing plant. Tip-burn appeared in abundance early in August on the lower level, and by August 22 at least half the leaves on the unsprayed area were lost, although not more than a fourth had died on the higher ground. The difference between the sprayed and unsprayed plants growing on the heavier soil was much greater than upon the lighter soil. Spraying saved at least half of the plants in the parts of the field worst affected.

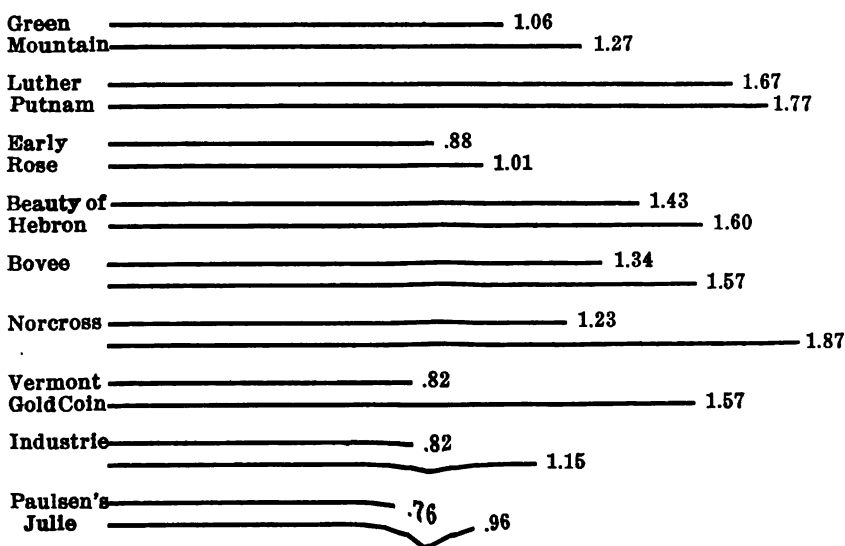
The crop was harvested in October. The yields, together with the plan of the field, are shown in the accompanying table. The results have been summarized for the sprayed and unsprayed plants of the varieties in the table. The yields in bushels per acre were as follows:

	Sprayed	Unsprayed
Green Mountain	192.	159.
Luther Putnam	250.5	265.5
Early Rose	151.5	132.
Beauty of Hebron	240.	214.5
Norcross	280.	184.
Bovee	235.5	201.
Vermont Gold Coin	216.	123.
Industrie	172.5	123.
Paulsen's Julie	144.	116.

The same results, expressed as pounds per plant, are diagrammatically set forth as follows:—

YIELDS IN POUNDS PER PLANT, 1914

(In each case the upper line represents the unsprayed and the lower line the sprayed plant).



Spraying had a favorable effect in all instances, except with Luther Putnam. In general the late potatoes were advantaged more than the early varieties, but even the early German variety, Julie, was benefited. The very light yields of Industrie and Julie were foreseen and are quite in accord with the experience of other investigators of potato problems who have introduced German varieties into this country, as is evidenced for example in bulletin 179 of this Station, pages 181-183. They are not acclimated to our short, hot summers and do not yield well. The early American varieties show less difference between the yields of the sprayed and unsprayed plants than do the later ones because they die before the effects of the bordeaux become apparent.

The yields from the supplementary plots emphasized the fact that the presence or relative absence of tip-burn account for the differences in yields on the sprayed and unsprayed plants. The earlier it appears and the more severe its attacks, the less the yield. The bordeaux spray retards its onset. The variation in the amount of tip-burn on the two ends of the field was reflected in their potato harvests. The average unsprayed plant on the heavy moist soil died young and produced only 1.02 pounds of tubers, while that on the higher land yielded 1.27 pounds. The differences between the yields of the average sprayed and unsprayed plants on the low land was 0.42 pounds; but on the high land it was only 0.25 pounds.

YIELDS FROM THE SUPPLEMENTARY SPRAYING (pounds per plant), 1915

(In each case the upper line represents the unsprayed and the lower line the sprayed plant).

East end of plot	_____ 1.27	_____ 1.52
West end of plot	_____ 1.02	_____ 1.44
Total plot	_____ 1.14	_____ 1.48

The west end of the plot was lower and the soil much heavier than that of the east end.

GREENHOUSE AND POT SPRAYING TRIALS IN 1914

The outcome of the experimental trials made in 1914 in and immediately back of the plant pathology greenhouse was most satisfactory. They furnished convincing evidence that the effect of the

bordeaux spray is conditioned upon climatic considerations. Larger pots and deeper benches might have been used to advantage, but on the whole the trials were a success.

Thirty-two plants were grown in the greenhouse. Medium sized Early Rose tubers were cut into pieces weighing from 35 to 36 grams. These were dried over night and planted April 17. Sixteen, all that were placed in one bed, rotted and were replanted on May 4 by similar pieces. Sixteen of the plants were sprayed with 5-5-50 bordeaux, alternate ones being chosen, on May 21, June 10, June 25, July 23, and August 25. The spray was applied as often as it washed off to any considerable extent. The plants were kept well watered and the greenhouse was well ventilated both night and day. Both the sprayed and unsprayed plants were examined for tip-burn, but not the slightest difference could be detected in the foliage. About a third of the tops were still green on October 6, but since the tubers were beginning to sprout it was thought best to harvest them.

GREENHOUSE EXPERIMENT

Sprayed or unsprayed	Number of tubers	East Bench		Sprayed or unsprayed	Number of tubers	West Bench	
		Weight of tubers grams	Average Weight grams			Weight of tubers grams	Average Weight grams
Sprayed	14	793	56.6	Unsprayed	6	170	28.3
Sprayed	13	585	45.0	Unsprayed	17	708	41.6
Unsprayed	11	920	83.6	Sprayed	13	522	40.1
Unsprayed	12	694	57.9	Sprayed	9	433	38.1
Sprayed	14	915	65.3	Unsprayed	11	397	36.1
Sprayed	11	538	49.0	Unsprayed	2	347	173.5
Unsprayed	10	1028	102.8	Sprayed	7	366	52.3
Unsprayed	7	412	58.8	Sprayed	5	521	104.2
Sprayed	14	688	49.1	Unsprayed	6	342	57.0
Sprayed	13	557	42.6	Unsprayed	7	700	100.0
Unsprayed	15	1055	70.3	Sprayed	5	313	62.6
Unsprayed	7	617	88.1	Sprayed	9	507	56.3
Sprayed	8	746	93.2	Unsprayed	10	373	37.3
Sprayed	16	787	47.9	Unsprayed	9	690	76.6
Unsprayed	11	982	89.2	Sprayed	8	406	50.7
Unsprayed	7	746	106.5	Sprayed	8	660	82.5
				Average weight tubers per plant in grams			
				Average weight tubers, grams			
		Tubers	Weight grams				
Unsprayed		148	10,181				
Sprayed		167	9,337				

Out-of-door pot experiments were carried on simultaneously with the greenhouse trials. Twenty zinc pots containing each about 6,000 grams of soil to which about 20 grams of potato fertilizer (4 percent nitrogen, 15 percent total phosphoric acid, 6 percent potash) had been added were planted on May 4 with Early Rose cuttings, each weighing

from 36 to 37 grams. The plants were left in the greenhouse until June 10, when they were removed to the open air and sprayed. They were sprayed also on June 25, August 9, and September 8. The foliage suffered greatly from tip-burn during the fourth week in August, when almost a third of it was thus destroyed. The malady was noticed first in mid-July, during a period of very hot weather. A high temperature during the day seems to be the direct cause of this disease, as has been shown many times. The bordeauxed plants suffered somewhat less than did those that were not sprayed. The soil in the pots was kept thoroughly moist, but painstaking care in this respect did not prevent tip-burn injury both to sprayed and unsprayed foliage. The entire top of the unsprayed plants, both leaf and stalk, was dead by August 15, whereas the sprayed plants still retained about half their foliage and all their stalks, although they were not of a healthy green color. All the unsprayed plants were dead on August 28 when they were harvested. The sprayed plants were harvested three weeks later on September 18, when a few stalks were still somewhat green. The results were as follows:—

POTATO PLANTS IN POTS, IN THE OPEN

Number of tubers	Unsprayed Weight of tubers grams	Average weight grams	Number of tubers	Sprayed Weight of tubers grams	Average weight grams
5	302	64.4	9	325	36.1
8	273	34.1	10	388	38.8
7	241	34.4	10	349	34.9
9	285	31.6	8	361	45.1
9	274	30.4	6	281	46.8
6	228	38.0	6	353	58.8
8	277	34.6	7	406	58.0
12	292	24.3	7	295	42.1
6	229	38.2	7	334	47.7
13	397	30.5	3	291	97.0
Total 83	2,798	33.7	73	3,373	46.2

It would appear from the results secured in this greenhouse trial where the soil was absolutely uniform, the climatic conditions fairly under control and the seed of uniform size:

1. That the yields were less from sprayed than from unsprayed plants.
2. That the tubers from the sprayed plants were smaller in size than from the unsprayed ones.

The potted sprayed plants grown outdoors increased in weight as compared with the unsprayed ones quite as much as usually is shown in our field trials. In both cases the plants were provided with the

same soil and an abundance of water. The difference in the outcome between the indoor and outdoor plants was clearly due to effects of the flea beetle and the tip-burn. On the indoor plants these troubles practically were absent; on the outdoor plants, they were very much in evidence and materially shortened the life of the unsprayed plants.

SPRAYING POTATOES, FIELD TRIALS, IN 1915

The potatoes used for the field sprayings were Irish Cobblers grown back of the farm buildings and planted late in May. Not more than half of the seed germinated because of *Rhizoctonia*. Many of the plants which grew were severely attacked by this disease and the field presented a sorry appearance.

The usual mixtures were applied on July 20, July 29, August 12 and August 24, the first spraying being delayed in the hope that more of the plants would grow.

The difference between the sprayed and unsprayed plants was very marked on August 30, the unsprayed plants being half dead while the sprayed ones hardly were touched. The brilliant sunshine of August 27-28 had produced this change. The foliage died rapidly between September 8 and 11 when the weather was hot and the sunshine brilliant. The unsprayed plants were from two-thirds to three-fourths dead at this time while the sprayed tops had lost not more than a third of their foliage. During the following two weeks the plants slowly died and harvest was begun on October 1. A few leaves infected with late blight were found as well as some affected with early blight. The amount of leaf disease of this sort was not of sufficient consequence to affect the results.

The tuber yield per sprayed plant was 2.18 pounds, 0.47 pounds of which were small and 1.72 pounds salable. The tuber yield per unsprayed plant was 2.08 pounds, 0.54 pounds of which were small and 1.54 pounds large.

SPRAYING PLANTS IN THE GREENHOUSE IN 1915

Early Rose tubers were planted on April 30 in parallel beds, the soil of which had been mixed so thoroughly that strict uniformity must have been secured. The seed pieces approximated 60 grams in weight. Ten plants were grown in each bed, and sprayed on June 10, June 17, and June 28. The potatoes were harvested on July 15, when the unsprayed plants were nearly all dead and the sprayed ones

about half dead. For some reason—probably more brilliant sunshine—the crop suffered from tip-burn to a greater extent than during the preceding season. The reduction in the intensity of the sunlight produced by the shelter of the greenhouse was not sufficient to prevent the premature death of the unsprayed leaves. Two further differences are to be noted; the potatoes were planted later in the season and the first spraying was done at a later date. The destruction of the leaf areas was of a somewhat different type from that which occurs in ordinary tip-burn. The browning instead of appearing on the ends and sides of the leaflets seemed to affect them in irregular spots and they succumbed as a whole and not in parts.

As was to be expected, in all cases where the unsprayed plants died before the sprayed ones the yields were relatively less. If the harvest had been delayed, the differences in yield would have been even larger for the reason that half of the sprayed plants were still living in mid-July whereas all the unsprayed ones had died.

RESULTS EXPRESSED AS GRAMS PER PLANT AND TOTALS

Unsprayed	.....	335	365	260	385	425	216	315	410	360	612	3,683
Sprayed	.....	475	425	255	655	370	477	312	265	280	455	3,969

SPRAYING POTATOES IN TILES 1915

Twenty large tiles 12 inches in diameter were filled with carefully mixed soil and manure and planted on May 16, Early Rose cuttings averaging 70 grams each in weight being used. Half of the number were sprayed on June 28, July 15, and August 11 the tops being at all times well covered by the spray mixture. Tip-burn was first noticed on the lower unsprayed leaves on July 25 and was quite marked by July 31. The tubers were harvested on September 10.

Number of tubers	Unsprayed		Number of tubers	Sprayed	
		Weight grams			Weight grams
41		1,158	35	.....	1,724
16		1,298	29	.....	1,788
32		1,118	14	.....	1,771
22		1,271	24	.....	1,463
18		947	43	.....	1,320
28		1,160	16	.....	1,618
23		998	22	.....	1,270
14		1,163	32	.....	1,268
21		1,297	22	.....	800
20		1,104	24	.....	1,393
235		11,514	261	.....	14,415

The difference in the yields is about same as usually is shown in field trials and is very similar to that obtained the preceding year. The

tip-burn and flea beetle injury, both of which were severe on the unsprayed foliage, seemed to be the cause of the lessened yield from the untreated plants.

SPRAYING BEANS, 1911

It is not easy to measure with certainty the outcome of spraying with plants other than the potato, for the reason that unlike that plant they possess no storage organ in which practically all the carbohydrates are held. Beans were used for two trials as it was felt that they met the requirements as nearly as any of our commonly cultivated plants. The bean contains a large percentage of protein and the assimilation of the starch into protein may be affected by the presence of the copper salts on the foliage in such a way that the process is rendered more difficult and more starch is consumed in the process. This consideration would have to be borne in mind if the yield in pods or beans is to be taken as a measure of the effect of the spraying on the plant. In spite of this possible complication the bean was used, since no better plant could be found.

Eight rows of bush beans were planted and the alternate rows sprayed in 1911. The beans were gathered on August 15 and 16 when they were about of the right size for shell beans. The pods are included in the weights.

Unsprayed	2,100 plants	38,502 grams beans	18.3 grams per plant
Sprayed	1,990 plants	38,464 grams beans	19.3 grams per plant

Alternate rows of bush beans were sprayed three times in the summer of 1912 in the Economic Botanical Garden at Bonn, Germany.

	Number of plants	Total weight of pods and beans grams	Weight per plant of pods and beans grams	Total weight of shelled beans grams	Weight per plant of shelled beans grams
Unsprayed	77	532	6.9	352	4.57
Sprayed	80	561	7.0	380	4.72

The differences in yield between the sprayed and unsprayed plants are so slight that soil variations easily might have produced them. The bordeaux spraying seems to have had no marked effect, either favorable or unfavorable. Bayer (6) claims to have secured very favorable results on the foliage following the spraying of the bean, but gives no figures showing comparative yields.

SPRAYING ARTICHOKEs IN 1913 AND 1914

Eleven 40-foot rows of artichokes were planted June 2, 1913. They were sprayed three times with 5-5-50 bordeaux. The

foliage did not seem to be affected. The plants were killed by the frost and the tubers left in the ground to come up the following spring. The same rows were sprayed twice during the summer of 1914 and the tubers were harvested October 2. The unsprayed rows yielded 324.6 pounds and the sprayed rows 297.3 pounds. Apparently the spraying, if it accomplished anything, tended to injure the crop.

2. MORPHOLOGICAL CHANGES

About twenty-five years ago, it began to be noticed that when grape foliage was sprayed with bordeaux, the leaves were thicker, of a bluish green color and lived longer than when they were left unsprayed. Rumm (36) seems to have been the first to call attention to these differences and his observations have been confirmed, especially on the potato plant, by later investigators such as Frank and Krüger (17), Schander (38), Ewert (16), Zucker (47), Aderhold (1), Harrison (20) and others. These changes undoubtedly are brought about by the absorption of minute quantities of copper into the leaf. This absorbed copper must be very small in quantity, otherwise the leaf would be injured or its physiological functions at least seriously interfered with. Some plants are able to absorb more of this copper without injury than others. The peach, plum, apple, and cherry are relatively susceptible, while spray injury, due to improperly made bordeaux with a consequent absorption of copper, is less frequent on the grape and potato. The copper taken into the growing leaves produces certain morphological changes in their structure. Rumm (36) made numerous measurements of the cells and thickness of the grape leaves, expressed as microns, the following of which will serve as an illustration:—

TWO LEAVES FROM A PLANT IN THE EXPERIMENT HOUSE, SEPT. 12

	Unsprayed microns	Sprayed microns	Increase microns
Thickness of leaf	156.63	172.92	+16.31
Epidermis	15.81	18.38	+ 2.57
Palisade tissue	55.07	61.87	+ 6.80
Parenchyma	85.75	92.69	+ 6.94

TWO LEAVES FROM A PLANT IN THE EXPERIMENT HOUSE, SEPT. 14

	Unsprayed microns	Sprayed microns	Increase or decrease microns
Thickness of leaf	155.02	157.19	+ 2.17
Epidermis	15.48	16.28	+ 0.80
Palisade tissue	53.82	59.18	+ 5.36
Parenchyma	85.72	81.73	— 3.99

The chlorophyll bodies in the palisade tissue of the sprayed leaves were somewhat smaller but more numerous than those in the unsprayed

leaves. The parenchyma cells from the sprayed plants were richer in chlorophyl and contained fewer vacuoles.

Frank and Krüger (17) record no measurements of leaves from sprayed and unsprayed potato plants. Their figures of leaf sections are diagrammatic, made only for the purpose of showing the relative amount of starch in treated and untreated leaves. They have made the observation, however, that the results secured from the potato plant agree with those attained with the grape, as Rumm has found; but the differences in thickness between the sprayed and unsprayed leaves are so small that they almost disappear in the sections. The difference in favor of some bordeauxed leaves is quite marked, while in other cases it is hardly noticeable; but it is never true that the unbordeauxed leaves are thicker than the treated ones.

Zucker (47) made a series of observations on the direct influence of bordeaux mixture on a variety of plants. These were not at all in agreement. *Nicotiana collossea* leaves seemed to be affected as were the grape and potato, but practically no change was wrought as a result of applying bordeaux on the leaf structure of *Ricinus communis*, *Colens hybrida*, *Pereskia aculeata*, *Begonia Lebrina*, *Eucalyptus tereticornis*, *Melalencia alba*, *Tydaea grandiflora*, *Cestrum roseum*, *Aralia pentaphylla* and *Juniperus Bermudiana*.

Lodeman (28) made the statement that spraying with bordeaux increased the thickness of plum leaves from 1.9 to 2.8 percent and of German prune leaves 10.2 per cent. Harrison (20) attempted to confirm his observations and found that plum, pear, peach and quince leaves were slightly thickened, probably because of the increased development of the palisade layer of cells, and that a marked development of chlorophyl granules occurred in the cells.

Schander (38) and Ewert (16) give no data touching the morphological effect wrought on the leaves by the mixture further than to verify the general observations previously made on plants thus treated.

Both Sorauer (39) and von Schrenk (40) have observed the formation of intumescences, the former on potato leaves, the latter on cauliflower, brought about by the action of copper salts on the cells of these plants. Sections of these growths showed them to be composed of parenchyma cells so strongly hypertrophied as to break the epidermis.

So far as the writer knows no careful measurements have been made of potato leaf cells secured from sprayed and unsprayed plants. The following data were derived from such studies of Green Moun-

tain leaves grown in the field. Part of the material was fixed in Flemming's solution, sectioned and stained, while part was preserved in weak formalin and free-hand sections used. Leaflets as nearly alike as possible in area were taken; Nos. 1 and 2 are comparable, Nos. 3 and 4, Nos. 5 and 6 and so on.

	Palisade parenchyma microns		Pulp parenchyma layer microns
1. Unbordeauxed, cells near margin ...	885	216	840
Unbordeauxed, cells near mid-rib....	858	204	990
2. Bordeauxed, cells near margin	1044	222	900
Bordeauxed, cells near mid-rib.....	876	192	1200-1350
3. Unbordeauxed, cells near margin ..	660	210	1050
Unbordeauxed, cells near mid-rib...	1042	228	1050-1200
4. Bordeauxed, cells near margin.....	1320	210	1500
Bordeauxed, cells near mid-rib.....	1950	300	1650-1800
5. Unbordeauxed, average thickness...	750 to	840	900- 960
6. Bordeauxed, average thickness.....	900 to	1050	1050-1140
7. Unbordeauxed, average thickness...	1050 to	1200	1050-1200
8. Bordeauxed, average thickness.....	1050 to	1200	1350-1500
9. Unbordeauxed, average thickness...		750	900-1050
10. Bordeauxed, average thickness.....		900	1050-1200
11. Unbordeauxed, average thickness...		900	1200
12. Bordeauxed, average thickness.....	1050-1200		1200

It will be noted from these data that the leaves from the bordeauxed plants show in general thicker palisade and pulp parenchymas than do the untreated ones. This hypertrophy is particularly marked in the length of the palisade cells of the leaf (fig. 9). The increase

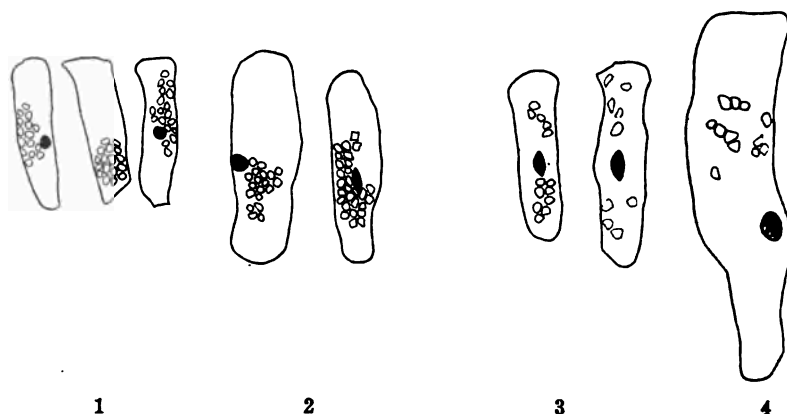


FIG. 9. Palisade cells from unsprayed and sprayed leaves. Nos. 1 and 3, unsprayed; Nos. 2 and 4, sprayed.

in the size of the cells was almost entirely in length but in a few cases where the hypertrophy was very pronounced, lateral bulging also occurred. The result of this stimulus was the production of long, comparatively slender, palisade cells. The morphological changes were less marked in the cells of the pulp. On account of their irregularity

it was impossible to make measurements of the individual cells of this layer, but the thickness of the entire layer usually is somewhat increased. It would be expected naturally that the cells immediately beneath would be affected most by the absorption of minute quantities of copper from the surface of the leaf, but no decided increase in the thickness of the epidermal cells could be observed. The stimulus seems on the other hand not to penetrate into the leaf to a sufficient depth to cause any large increase in the size of the pulp cells. No indications were seen of a dying off of the epidermal cells and a lengthening of the palisade cells into long tube-like growths deficient in chlorophyll, as described by Sorauer (39). The possible explanation for the appearance mentioned by Sorauer is the presence of little uncombined copper in the mixture applied, although it may have been brought about by unfavorable weather conditions, for he notes that these abnormal growths occur also on the unsprayed leaves. He explains this hypertrophy of the palisade cells as due to the diminished powers of assimilation of these plants accompanied by the presence of too much water.

It was difficult to count the number of chlorophyll bodies in the cells, but there seemed to be some increase in their number in the cells derived from the sprayed plants. If the hypertrophy of the cells was very great, however, the individual chloroplasts also were enlarged. The nucleus also was increased in size noticeably in the abnormally large cells.

The real physiological disturbance which produces these unusually large cells is difficult to locate, but an increased turgor is the probable immediate cause. The way in which this turgor is brought about is not clear. Ewert's theory (16) that the presence of copper salts interferes with the removal of the starch during the night, might have a bearing also on the turgidity of the cells from which this starch is removed. The constant presence of glucose, due to its slow removal under these conditions, would tend to raise the osmotic concentrations of the cell sap and probably would tend to increase turgor.

3. PHYSIOLOGICAL CHANGES

The morphological effects produced by spraying plants with bordeaux mixture seem to be followed by physiological changes which manifest themselves in the yield of tubers. The cultivated potato, it should be pointed out, is the most perfect starch producing machine that man has found, and consequently is the best plant available for

measuring such effects. The slightest disturbance in any of its ordinary functions may affect either favorably or unfavorably the quantity of the potato tubers produced. The appearance in America of the sprayed plants as compared with those unsprayed is markedly modified as shown by:

- (1) The dark green color with increased chlorophyl content.
- (2) The thicker leaves and sturdier stalks.
- (3) The longer life—ten days to two weeks—of the crop.

All this would lead the observer to expect an increase in the weight of tubers produced by sprayed plants. This expectation has been confirmed without exception by every American investigator who has sprayed potatoes with bordeaux. The longest unbroken record in this country of such sprayings is that of the Vermont station, where work was begun in 1891 and now has been carried on for a quarter-century. During at least a third of these 25 seasons very little disease appeared in the fields. Under such conditions any increase following the use of bordeaux must have been due to some action other than a fungicidal one. The smallest increase due to the spraying during all these years was that obtained in 1906, namely 32 bushels per acre, while as high an increase as 72 bushels per acre is recorded in years when no disease such as late or early blight caused a loss in the foliage or tubers of the unsprayed plants. The New York (Geneva) station has practiced spraying since 1902, and the results it has obtained have paralleled those secured during the same seasons at Vermont (41). These trials were conducted not only at Geneva but at other points throughout New York State, and always with favorable results. An increase of 39 bushels per acre in 1908 from the plots sprayed at Geneva was noted; and 1908 was the sixth year in which neither early nor late blight infestation occurred and in which no potato rot was in evidence. These favorable results are ascribed by the New York botanists to the protection afforded the plants against flea beetle and tip-burn. It has been noted repeatedly at both these stations that the increase in yield brought about by the use of bordeaux is in the marketable tubers. The amount of culls usually remains about the same.

Numerous shorter trials have been made in various parts of the United States which corroborate the results of these two long-time experiments. For example Giddings (18) in West Virginia found in 1909 that three applications of bordeaux increased the yield 53.5 percent and that four applications in 1910 augmented it by 39.3 percent.

The unanimous verdict of all American observers and investigators to the effect that spraying the potato crop with bordeaux mixture is worth while and that usually it "pays," is in marked contrast to the point of view expressed by European students of potato culture, based on the results secured in similar experiments. These have been made in almost countless numbers. The fact is that the physiological effect of bordeaux seems to vary in different regions, soils, and years. Kirchner (24) has collected six instances in which the sprayed potatoes yielded a smaller harvest than the unsprayed; four in which at least some of the sprayed varieties yielded a greater weight than the unsprayed, an increase brought about by the lengthened life of the sprayed plants; and five instances in which, for some reason which he does not understand, the sprayed plants yielded more than the unsprayed ones. His own results with bordeaux secured in 1904, 1905 and 1907 are cited below, the yield from the unsprayed crop being expressed as 100 in each case.

1904. *Leo*. Sprayed 3 times with 1 percent strength bordeaux,¹ 97.9 percent; 4 times, 1 percent strength, 92.2 percent; 5 times, 1 percent strength, 92.2 percent; 6 times, 1 percent strength, 93.9 percent.

1905. *Cimbal's Früthe Reichtragende*. Sprayed 3 times with 0.5 percent strength bordeaux, 112.1 percent; 1 percent strength, 121.1 percent; 2 percent strength, 115.4 percent; 3 percent, 109.9 percent.

1907. *Olympia*. Sprayed 4 times with 2 percent strength bordeaux, 64.4 percent (starch content, 68.4 percent, starch content of unsprayed plants being 100).

The sunshine, both in quantity and intensity, was very much below the normal for July and August, 1907, and it is to this factor that Kirchner ascribes the low yield from the sprayed rows. A normal amount of sunlight had occurred during other growing seasons and the results were more nearly those likely to be secured during an average summer. The conflicting results obtained by different investigators are due, therefore, according to Kirchner, partly at least to seasonal differences. The shading produced by bordeaux on the foliage in seasons when all the sunlight available should be utilized, results in a lessened yield, while the foliage is protected from excessive sunlight in summers when it is abundant and strong.

PREVIOUS WORK ON THE PHYSIOLOGICAL EFFECT OF BORDEAUX

It is to be expected of course that a problem such as that of the influence of bordeaux mixture on plants, having both great practical

¹One percent bordeaux corresponds approximately to the 5-5-50 mixture; 2 percent, to the 10-10-50 mixture and 3 percent in the 15-15-50 mixture.

and scientific interest, should be taken up by a number of investigators. The results which they obtained and the theories based thereon are so divergent that it seems necessary to review the work of each individually.

Rumm (35) found that he was unable to detect spectroscopically the copper lines in the ashes of sprayed leaves which had been carefully washed of all external traces of bordeaux mixture. Hence he held that the effect of the copper salts in the mixture was not due to minute quantities which had been absorbed, but to chemotactic influences due to the presence and intimate contact of the copper salts with the cell walls. This stimulus of the copper salts acts on the life functions of a plant in a similar manner as does light and gravity, and expresses itself in an increased production of chlorophyl. This unjustifiable extension of Pfeffer's theory as to the production of chemotactic influence in the plant has not been regarded with favor by any succeeding investigator with the exception of Zucker (47). Rumm was convinced that the application of bordeaux had a favorable effect on sprayed plants, due largely to the lowering of transpiration. He maintained that the copper-lime combination stimulated those forces which hold the water in the living cells and that whether the chlorophyl content of the leaves was made larger or smaller as a result of the use of bordeaux was a matter of secondary importance.

Frank and Krüger (17) were able to state that spraying potatoes with copper increased the yield in those years in which the plants were free from *Phytophthora* infestation. The harvest from sprayed and unsprayed plants in 1893, a very dry season in Germany, stated as kilograms per plant, was as follows:—

	Early Rose	Fürst von Lippe
Unsprayed	0.175	0.168
Sprayed with lime	0.178	0.217
Sprayed with weak bordeaux	0.180	0.169
Sprayed with strong bordeaux	0.189	0.175

The actual presence, shown both macroscopically and microscopically, of more starch in the sprayed leaves than in the unsprayed ones was demonstrated by means of the Sach's iodine test on leaves from which the chlorophyl had been removed by alcohol. Sections of sprayed leaves showed the chlorophyl bodies filled with large starch grains in contrast with the small and less numerous ones seen in unsprayed cells. The favorable influence of bordeaux on potato plants, as evidenced in an increased yield of tubers, was held by these investigators to be a result of increased transpiration in the sprayed plants.

and of their lengthened life. No explanation is offered as to the cause of the increase of transpiration following the application of copper salts to the foliage; although these authors suggest that the key is to be sought in the stronger assimilation of such leaves, an increased formation of material going hand in hand with an increased use of water. No theory of any sort is advanced as to the lengthened life of the sprayed plants, but the trials showed that it was due to the copper for the reason that the leaves sprayed with lime alone died as promptly as did those left unsprayed.

Aderhold (1) stated it as his opinion that the favorable results received with bordeaux were not due to the lime or copper sulphate, but to the traces of ferrous sulphate that are always present as an impurity in copper sulphate, three commercial samples of which on examination were found to carry .052, .034 and .052 percents of ferrous sulphate. The favorable action of iron salts in chlorophyl formation long has been recognized in the treatment of chlorosis in grape vines. The results of experiments on beans sprayed in part with bordeaux made from chemically pure copper sulphate and in part with that made from the commercial salt, convinced him that iron played an important role in the favorable effect of the mixture.

Zucker's contribution (37) was an extension of Ruim's and of Frank and Krüger's work to a large number of plants, the majority of which were greenhouse species. Plants sprayed with bordeaux showed greater resistance to etiolation than did unsprayed ones; their chlorophyl contents were increased, a stimulated power of assimilation was evident, and the shoot lived longer. Without a single exception among the plants used in these experiments, those sprayed with bordeaux transpired more than did either the unsprayed or those sprayed with lime alone. Zucker's explanation was to the effect that some sort of electrical force acted between the salt solutions in the cell sap.

Bayer (6) made use of bordeaux and various other compounds of copper in culture solutions in an endeavor to ascertain what effect these salts had on the root systems and foliage when taken into the plant body in connection with the nutrient materials and water. It is not necessary to discuss this phase of the absorption of copper compounds here, as probably it is quite different in its effect from a similar absorption through the foliage. Bayer was unable to confirm Frank's, Krüger's and Zucker's observations that sprayed plants transpire more than do unsprayed plants. In two trials with potatoes he found transpiration to be slightly increased where spraying had been

done, but the reverse was found to be true with bean and pea stalks. He felt that the lessened transpiration in these plants was caused by the lengthening of the palisade cell spaces in the pulp parenchyma; that long palisade cells expose less surface to the exterior and, therefore, transpire less than do shorter ones possessing more end surface under the epidermis.

Schander (38) in a very long paper on this general subject supports strongly the stimulus theory. He holds that the copper penetrates the leaf in small quantities, probably less than one part in a hundred million, and there produces changes in the assimilation and transpiration of the foliage. He disregards the influence of the lime and of the iron in the copper sulphate. He ascribes the favorable results to the shading produced by the bordeaux on the upper surface of the leaves. The assimilatory tissues lying beneath the epidermis are protected in this manner from the injurious excess of sunlight and the amount of carbon dioxid is fixed in larger quantity than it would be if the plant were exposed to the full strength of the light. Increased assimilation from the use of the mixture is obtained in very dry seasons such as 1892 (Rumm), 1893 (Frank and Krüger), 1896 (Aderhold), while unfavorable results may happen in summers that are very wet or cloudy, as was 1891 in part, when Sorauer carried on his field experiments. He states that the difference in color between sprayed and unsprayed plants goes back to the same cause; that shaded plants always are a darker green than those exposed to the full sunlight. He finds, as do others whose work is cited, that transpiration is diminished about 10 percent in sprayed plants, but he believes that this is due to the slight lowering of the temperature resulting from the shading, a difference of 0.1 to 0.5 degrees C.

Ewert (16) attempted to solve the problem of the effect of bordeaux on plants by means of pot cultures grown under carefully regulated conditions of soil and temperature. The zinc vessels used as pots each contained the same quantity and quality of soil; tubers of the same size were planted in them; the soil was maintained at a definite saturation; and the plants were carefully rolled in and out of a shelter house at night and during rains. Ewert intended to verify or disprove the Schander theory that the favorable action of the bordeaux was due to the shading which the mixture produced on the leaves. A part of the plants, therefore, were grown under green or white cloth or white gauze screens. Field experiments also were made under similar conditions. The results obtained indicated that in all

instances the spraying with bordeaux, the shading with cloth, and the combination of the two, diminished the yield of tubers. The amount of water used on the several pots was recorded. Those containing sprayed plants lost by transpiration less than those containing the untreated ones. The respiration of the sprayed plants was slightly lowered by the treatment; this was never marked, but was very constant.

Ewert's most original contribution to this question was his discovery that the bordeauxed plants contained more starch in the morning in the leaves than did those which had not been thus treated; not because they were making more starch but because they were unable to get rid of it as rapidly as do the unsprayed ones. This results in a heaping up of starch in the chlorophyll bodies and the impression is that their assimilation is greater than is that of those derived from untreated leaves, a point of view accepted by every other investigator who has tested them according to the Sach's method. Ewert has pointed out that even after 16 hours in the dark the starch is still held in patches in the sprayed halves of leaves taken from the same plant. The retarding of the removal of the starch is due to the action of the copper on the diastase. By means of experiments made outside the plant, Ewert (15) was able to show that even in a concentration of one part of copper sulphate in thirty million of water, the action of small quantities of diastase on starch was prevented. This small percentage of copper easily might be absorbed by the plant, thus preventing the removal of the starch at night. This work was very carefully done and the conclusions as to shading and the effect of copper on the diastase of the leaves are thoroughly worthy of consideration.

(a) WHICH CHEMICAL CONSTITUENT STIMULATES THE POTATO PLANT?

Aderhold's (1) contention that the iron sulphate nearly always present in commercial copper sulphate is the cause of the brilliant green color of sprayed plants, had already been disproved by Ewert (16) under European conditions, but it was thought well to devote one season's field trials to a test of this matter, especially as this country is the only one in which consistently favorable results are obtained when bordeaux is applied. Plots of Green Mountain potatoes were sprayed in 1909 with the ordinary 5-5-50 bordeaux formula, with bordeaux containing iron sulphate, (2 pounds copper sulphate, 4 pounds iron sulphate, 6 pounds lime, 50 gallons water) and with iron sulphate and lime, (5 pounds iron sulphate, 5 pounds lime, 50 gallons water).

Control plots were dusted with paris green and lime. The foliage of the plants on the two plots which were sprayed with the compounds containing copper were the only ones which showed the dark bluish green appearance characteristic of plants sprayed with copper compounds. The plants sprayed with iron sulphate and lime were as yellowish green in appearance as were the controls. The yield of tubers in bushels per acre confirmed these observations on the foliage:—

Treatment	Marketable tubers bushels per acre	Small tubers bushels per acre	Total yields bushels per acre
Bordeaux (5-5-50)	192	51	243
Bordeaux-iron sulphate (2-4-6-50)	184	51	235
Iron sulphate and lime (5-5-50)	117	51	168
Control (paris green and lime)	138	50	188

The yield on the plots sprayed with iron sulphate and lime was less than it was on the control plots. These results seemed to prove conclusively that in this country, as Ewert showed was the case in Germany, the copper is what changes the appearance of the foliage and augments the tuber yields. Hence no further experiments along this line were attempted.

(b) DOES THE COPPER PENETRATE INTO THE PLANT STRUCTURE?

In view of the fact that negative results were obtained by Frank and Krüger (17) and by Rumm (35) when applying spectroscopic analysis to the ash of the foliage of sprayed plants, it would appear that if the copper really does enter the leaf it must be in very minute amounts. However, Ewert (15) was able to demonstrate by its action on the diastase that copper was present in the sprayed leaf in minute traces. Indeed there now seems to be no reasonable doubt that it can be absorbed by the leaves. Pickering (34) found that nine apple leaves, with a weight of 9.7 grams and an area of 60 square inches, reduced in 24 hours the amount of copper in 275 cc. of .001 solution of copper to .0007, and after three days, to .0004. He was also able to demonstrate, chemically, the presence of copper in sprayed apple and orange leaves.

The effect of copper on the keeping qualities of chlorophyl in solution was first noted in the Vermont laboratory in some sprayed and unsprayed plants preserved during the summer for a comparative determination of the amount of chlorophyl. The alcohol containing the sprayed plants retained a brilliant dark green hue, while that containing the unsprayed tops was greenish brown. Some of the copper salts from the exterior of the sprayed plants were still clinging to

them and aided in their preservation. Alcoholic extracts of potato chlorophyll were made and to them was added 0.1, 0.01 and 0.001 percents of copper sulphate. These solutions, together with a check tube of chlorophyll, then were exposed direct to the sunlight for about an hour. The chlorophyll in the check tube became a brownish green, the liquid in the tube containing the 0.1 percent was unchanged whereas those in the 0.01 percent and 0.001 percent tubes were both much greener than the solution in the tube containing no copper salts. Two plants were placed over night, upside down, in a jar containing 0.1 percent solution of copper sulphate, while two were placed in tap water. The former lot were more flaccid in the morning than the latter. Solutions of chlorophyll made from these plants showed the same differences in their resistance to the action of sunlight that was shown in the previous experiment, the plant having taken up enough copper during the night to make its resistance to the destructive action of the sunlight very marked. Plants treated in a similar manner were dried in the direct sunlight. The plants from the copper sulphate solution remained bright green even when kept for weeks in the sunlight, while the check plants turned a greenish brown in drying. The bordeaux mixture was washed from sprayed potato plants grown in the greenhouse by means of weak acid and water until no trace of copper showed in the washings. An alcoholic solution of chlorophyll was then made by boiling the plants and extracting some of the coloring matter with 95 percent alcohol. The resistance to sunlight of the chlorophyll thus recovered from the sprayed plants seemed to be somewhat greater than that derived from the unsprayed plant, but the differences were not marked. The difficulty experienced in extracting the chlorophyll by means of alcohol from sprayed plants already has been noted by Ewert (16). It is a slow process even after the plants have been boiled previously in water. The copper salts evidently enter into some sort of chemical union with the chlorophyll, forming a substance which is very tenacious in its hold on the proteid substratum of the chlorophyll bodies and which renders the coloring matter much more stable in the presence of direct sunlight. The determination of the nature of this combination is a difficult chemical problem, but the compound called by Tschirch (43) copper phyllocyanate probably is the one which is formed. Tschirch found that the chlorophyll in the skins of the grapes unites during the process of fermentation with the copper salts derived from this compound in an insoluble form, thus serving to remove the copper from the wines made from grapes that have been sprayed.

(c) WHAT EFFECT HAS COPPER ABSORPTION ON LEAF FUNCTIONS?

An increase in the amount of assimilated carbon dioxide apparently is the visible external evidence of the absorption of copper by the potato leaf. Under American climatic conditions, sprayed plants always yield more tubers by weight than do unsprayed ones. The external appearance of the sprayed plants—dark green foliage and thick stalks—apparently would confirm this result. On the other hand, the early death of the unsprayed rows would seem to indicate that this increase is due in the main to the longer life of the unsprayed plants. The problem is further complicated in America by the presence of tip-burn. The cause of this disease has been discussed at much length in former publications of this Station and is further reviewed on page 79 of this bulletin. It always is present in this vicinity during August and may appear as early as July 15. Its effects are shown much more severely on the unsprayed plants than on those treated with Bordeaux. An attempt has been made during two years to determine whether spraying increases the yield even before tip-burn gets a hold on the plants and kills much of the foliage. This attempt was more easily stated than accomplished for the reason that tip-burn is liable to show itself before much spraying can be done, and before its effect becomes manifest on the foliage. The earliest harvest of potatoes for this purpose was made in early September, and even at this date tip-burn already had done some foliage damage, as may be seen by an examination of the comparative weights of the tops of the sprayed and unsprayed plants.

	Large tubers bushels	Small tubers bushels	Total bushels	Average weight of tops pounds
1910 Bordeaux	167.9	26.9	194.8	0.809
Sept. 2 Control	130.5	39.2	170.	0.753
1912 Bordeaux	104.5	15.3	119.8	0.668
Sept. 4-5 Control	73.1	14.	87.	0.475

These results show, however, that copper mixtures exert a favorable effect on the plant within a short time after they are applied. The tip-burn and flea beetle already have done more injury to the control plants within this short time than to the sprayed ones and it is doubtful if field experiments can be carried out in Vermont which will be free from this difficulty. Furthermore, the inevitable and unavoidable differences in soil in several parts of a field also lead to yield variations that are likely to convey false impressions. Even when an experiment is repeated a number of times in the same field, the effects of this

source of error are not nullified. It is only when results are obtained for a series of years and from a number of plots and when the differences are pronounced that one can dogmatize as to the outcome of field experimentation. Hall and Russell (19), as a result of the three-quarters of a century of soil and plot work at Rothampsted, where the operations always have been done with the utmost care and where the general conditions tend to favor accuracy in experimental work, consider it unsafe to lay stress on differences of less than 15 percent. Experiments made under greenhouse conditions and pot experiments conducted after the manner of Ewert's trials alone will serve to enable one definitely to determine whether spraying a plant actually causes its stimulation and an increase in its daily starch output. However, greenhouse experiments do not duplicate our weather conditions either as to light, temperature or humidity, and are of interest only when viewed from a scientific standpoint and for the particular conditions which they represent. It would seem, therefore, that pot experiments, so conducted as to give to all the plants uniform soil conditions and as to control the open air surroundings, temperature, light and humidity, represent the only safe procedure to adopt.

Granting that some of the physiological changes are brought about in the plant and are expressed in their varied yields, it is next necessary to inquire into the ordinary functions of the plant in order to determine, if possible, the one affected by the presence of the spray mixture on the outside of the foliage and of traces of copper salts inside the plant. These functions may be summarized as:—

The absorption of water by the roots.

The transpiration of this water by the leaves.

The assimilation of carbon dioxide for starch formation.

The removal of the products of starch assimilation.

The respiration of carbon dioxide.

The formation of proteids and other nitrogenous products.

The synthesis and destruction of chlorophyll.

TRANSPIRATION

The absorption of water by the roots and its transpiration by the leaves are correlated so nearly that they may be considered together. A comparison of sprayed and unsprayed plants would lead inevitably to the conclusion that the former took up more and gave off less water than the latter. Their succulent foliage and comparative freedom from tip-burn tells the story. Tip-burn has all the superficial appearances of a disease caused by a lack of water or by excessive transpiration.

Data on the effect of bordeaux on transpiration are very contradictory. Rumm (35) and Schander (38) are of the opinion that it tends to lessen the amount of water given off, and Ewert (16) is apparently one with them in their belief. On the other hand, Frank and Krüger (17) Zucker (47) and, more recently, Duggar and Cooley (13, 14) have shown that in potted potato plants the leaves covered with bordeaux mixture transpire more water than do those which lack such a covering. This difference was increased further by the addition of lampblack to the bordeaux and was true also of leaves covered with the lime wash. The lime-sulphur probably was too dilute (1 to 25) to produce very much effect. It would seem as if a problem of this nature would be solved easily. There must be some flaw in the methods used or the results obtained would have been more consistent.

In the first trials conducted at this Station, branches of bordeauxed and unbordeauxed plants were brought in from the field and the amount of water transpired in the shade for a period of about two hours determined by means of a Ganong potometer. The leaves were weighed in one trial, and in the others the leaf surfaces were determined by means of a planimeter.

No.	Plant	Time ¹	Total water transpired cc.	Transpira- tion per minute per gram of leaf weight cc.	Leaf area square inches	Transpira- tion per minute per square inch leaf surface cc.
1.	Unbordeauxed,	9:49-11:48 a. m.	.6 in 119 min.	.00059		
2.	Bordeauxed,	9:40-11:54 a. m.	.75 in 137 min.	.00076		
3.	Unbordeauxed,	4:00- 6:15 p. m.	1.26 in 124 min.		37.50	.000266
4.	Bordeauxed,	4:00- 6:35 p. m.	.92 in 146 min.		47.82	.000131
5.	Unbordeauxed,	2:38- 4:21 p. m.	1.54 in 97 min.		56.26	.000187
6.	Bordeauxed,	2:38- 4:45 p. m.	1.18 in 120 min.		52.49	.000282
7.	Unbordeauxed,	8:48-11:05 a. m.	1.00 in 134 min.		51.39	.000145
8.	Bordeauxed,	8:48-11:32 p. m.	.92 in 157 min.		50.44	.000116
9.	Unbordeauxed,	8:54-11:16 p. m.	1.77 in 115 min.		53.89	.000285
10.	Bordeauxed,	8:57-11:54 p. m.	1.20 in 177 min.		43.04	.000157
Average of four unbordeauxed plants per square inch of leaf surface per minute .....000229 cc.						
Average of four bordeauxed plants per square inch of leaf surface per minute .....000171 cc.						

These results were obtained on five different days. They seem to show that under these conditions the unbordeauxed plants transpire more water than the bordeauxed ones. The brief time during which the leaves were under observation as well as the unusual conditions under which the plants were placed, led the writer to feel that perhaps

¹The time is given only to indicate the part of the day in which the experiment was performed. In a majority of the experiments some time was taken out while the apparatus was being readjusted.

they were not transpiring at all normally. The amount of water transpired per minute per square inch of leaf surface was so very small as to raise doubts in his mind. Hence other means were devised in order to check these results. The simplest of these was aimed to determine the amount of water given off by the treated and untreated potato plants when wilting. Three large potato branches that had been bordeauxed and three slightly smaller ones that had not been thus treated were brought from the field into the laboratory at nine o'clock. They were placed on a table, in the shade, near a window through which a current of air was passing. Their weights were:—

	9 A. M. grams	2:30 P. M. grams	Loss grams
Bordeauxed plants	174	130.5	43.5
Unbordeauxed plants	132	113.	19.

A similar experiment on the following day, using eight branches resulted as follows:—

	9:20 A. M. grams	2:30 P. M. grams	Loss grams
Bordeauxed plants	219	172	45
Unbordeauxed plants	214	184	30

These eight branches were kept in the laboratory for a week and then were placed in the open sunshine for three days to air dry.

	Weight after a week had elapsed grams	Weight after three days more additional sunshine grams	Loss from original weight grams	Percentage loss
Bordeauxed plants	35	18	201	91.8
Unbordeauxed plants	46	23	191	89.2

This result also would seem to indicate that the bordeauxed plants were slightly more succulent than the unbordeauxed ones.

Similar trials were made with sprayed and unsprayed potato (Industrie) plants from the Economic Botanical Garden at Bonn. The weights of the young and old leaves were kept separate.

	Weight at 10 A. M. grams	Weight at 12 A. M. grams	Loss grams	Percentage loss
6 old leaves, bordeauxed.....	25.5	19.5	6.	23.5
25 young leaves, bordeauxed....	22.8	17.9	4.9	21.
6 old leaves, unbordeauxed.....	29.3	25.	4.3	15.
25 young leaves, unbordeauxed...	19.	17.3	1.7	9.

Leaves taken from freshly bordeauxed plants gave these results:—

	Weight at 8:30 P. M. grams	Weight at 2:30 P. M. grams	Loss grams	Percentage loss
7 old leaves, unbordeauxed.....	35.5	30.3	5.2	14.5
30 young leaves, unbordeauxed..	20.	18.7	2.1	9.
12 old leaves, bordeauxed.....	41.5	34.4	7.1	17.
30 young leaves, bordeauxed	18.7	16.6	2.1	11.

On August 9 several plants were allowed to air-dry:—

	Weight at 10:30 A. M. August 9 grams	Weight August 17 grams	Loss grams	Approximate percentage dry matter
11 large leaves, bordeauxed.....	35.3	7.3	28.	20.
32 small leaves, bordeauxed	22.3	4.2	18.1	18.8
9 large leaves, unbordeauxed....	43.7	7.4	36.3	16.9
34 small leaves, unbordeauxed....	25.7	4.8	20.9	18.5

The bordeaux still clinging to the sprayed plants readily would account in this case for a part of this apparent difference in the percentage of dry weight. The plants had been sprayed recently and there was considerable copper salt still adhering to the dry foliage.



FIG. 10. Apparatus used in transpiration experiments.

The study of the transpiration end of the problem was resumed in the spring of 1914, using potato plants grown in the greenhouse. These plants were sprayed twice in order to insure a thorough coating of the leaves with the mixture, and being about two-thirds grown, were placed in potometers of the form shown in figure 10. Plants as nearly as possible of the same size and shape as the sprayed ones were placed in other potometers. It was found easier to ascertain moisture losses by weight than by measurement. Three trials were

carried on inside the greenhouse during March and April, and three were conducted for the most part in the open air in early September, using plants grown and sprayed in the open. The plants were weighed twice daily and, after the conclusion of the experiment, the leaves were removed and weighed. Leaf surface areas were determined by means of a planimeter during the first two experiments.

	Weight of leaves grams	Leaf surface sq. cm.	Total transpiration grams	Transpi- ration per gram of leaf grams	Transpira- tion per sq. cm. grams	Trans- pira- tion per sq. cm. grams
GREENHOUSE TRIALS						
Unbordeauxd ..	27.5	103.9	121.5	4.4	1.17	
Unbordeauxd ..	55.5	274.9	194.	3.5	0.70	0.93
Bordeauxed	25.5	96.27	130.5	5.1	1.35	
Bordeauxed	43.5	181.15	186.	4.3	1.02	1.18
Unbordeauxd ..	42.5	169.73	133.	3.1	0.78	
Unbordeauxd ..	42.5	194.81	145.	3.4	0.74	0.76
Bordeauxed	38.5	164.9	147.	3.8	0.89	
Bordeauxed	30.5	125.35	157.	5.1	1.25	1.07
Unbordeauxd ..	18.		73.	4.		
Unbordeauxd ..	23.		67.	2.9		3.5*
Bordeauxed ...	31.		111.	3.6		
Bordeauxed ...	30.		102.	3.5		3.6*

OUT-OF-DOOR TRIALS						
Unbordeauxd ..	92.5		361.	3.9		
Unbordeauxd ..	87.		295.	3.4		3.7*
Bordeauxed ...	132.		421.	3.1		
Bordeauxed ...	132.		526.	3.9		3.5*
Unbordeauxd ..	130.		933.	7.1		
Unbordeauxd ..	169.		830.	4.9		6.*
Bordeauxed	124.		977.	7.9		
Bordeauxed ...	169.		906.	5.3		6.6*
Unbordeauxd ..	192.5		468.	2.4		
Unbordeauxd ..	186.5		365.	1.9		2.2*
Bordeauxed ...	234.		515.	2.2		
Bordeauxed ...	189.		414.	2.2		2.2*

An examination of these data shows that in two cases more water was given off in the greenhouse by the bordeauxed plants than from the unsprayed ones and that in the third the results were indeterminate. In one of the experiments made in the open air water losses from sprayed plants exceeded those from unsprayed plants, and in the other two trials the results were essentially alike.

The results of these experiments may be summed up as follows:

		Greenhouse	Open air
Weight of leaves (grams)	Unbordeauxd	209.0	857.5
	Bordeauxed	199.0	980.0
Transpiration (cubic centimeters)	Unbordeauxd	733.5	3252.0
	Bordeauxed	833.5	3759.0
Transpiration (cubic centimeters per gram weight)	Unbordeauxd	3.5	3.79
	Bordeauxed	4.2	3.83

*Average transpiration per gram of leaf stated as grams.

The general conclusion that may be drawn from the foregoing tabular statement is that transpiration is slightly increased by spraying, especially under conditions where there is no rapid circulation of air. The difference is so slight, however (only about 1 percent) that the small loss readily might be compensated for by the plant. Even the interjection of a pane of glass between the plant and the sunlight is sufficient to change the amount of light and heat. The only thing than can be said of such experiments is that while they are correct for the given conditions they might not hold for others.

RESPIRATION

No experiments have been conducted at this Station to determine the effect, if any, of spraying on the passage of carbon dioxid from the plant. Any attempt carefully to control an experiment leads to the introduction of all sorts of abnormalities, and no method has been devised as yet that will avoid such difficulties. Ewert's (16) careful experiments have shown that a bordeauxed plant requires much less carbon dioxid than does an unbordeauxed one when the two are placed under a belljar and the amounts of respired carbon dioxid are measured. The condition and behavior of a plant growing under a belljar must be different from that of the same plant in an open field.

STARCH REMOVAL

Sections of leaves that have been sprayed with bordeaux usually show, as was figured by Frank and Krüger (17), chlorophyl bodies stuffed with large starch grains while the same organs in the unsprayed leaves contain fewer and smaller grains. Ewert (16), while not denying the presence of an increased starch content in the sprayed leaves, asserts that its presence is due to the inability of these cells to remove it as fast as it is formed. He has shown that copper compounds retard the action of diastase and that an accumulation of starch occurs in the chlorophyl. Sprayed leaves, decolorized by the action of alcohol with their starch stained blue with iodine according to Sach's method, show bluish patches even after they have been kept in darkness for 24 hours, whereas untreated leaves kept under similar conditions lose all their starch. It is comparatively easy to confirm the observations both of Frank and Krüger and of Ewert. The starch in bordeauxed leaves, even after they have been kept in darkness for some time, still remains in spots. These starch-holding areas seem to exhibit no regular arrangement or size, but they occur more frequently near the base of the leaves than elsewhere. An attempt was made to

correlate them with injured portions of the leaf, but, so far as could be made out, the parts of the leaf containing starch were as normal as the remainder. The probability is that these parts were covered by a layer of bordeaux in which much free copper had been given off and under which the cells had absorbed enough to prevent the action of the diastase. The action of the copper salts is local in its effects. Spots of this nature would be likely to result if any appreciable amount of copper were absorbed by the underlying tissues.

CARBON DIOXID USAGE

Does a sprayed plant use more carbon dioxide than an unsprayed one? In studying this question Amos (2) used the Brown and Escombe method. Similar leaves from the same plant were taken, air and carbon dioxide drawn through glazed cases in which the leaves are exposed and the carbon dioxide contents of the inspired and expired air were determined. The results obtained on grape leaves are fairly typical. The ratio expresses the average absorption per square decimeter, the sprayed leaves being represented as unity.

July 28, 29, 31	1 : 1.02
August 4, 5, 10	1 : 0.79
August 18, 20	1 : 1.03

Amos inferred that the application of bordeaux mixture to plant leaves diminishes their carbon dioxide assimilation for a time, but that this effect gradually wears off.

(d) SHADING AND TEMPERATURE EFFECTS

The intensity of the sun's rays is much reduced to a leaf which is covered by a heavy coating of bordeaux mixture. This effect is of much more importance in America than in the great European potato growing countries for the reason that, owing to our lower latitude, the light is much more intense. The air, too, is less hazy than in England and Germany where the moisture laden west winds blow.

The bordeaux-mixture collects and dries on the tips or along the veins of a leaf. These portions are thus protected from the destructive action of the sunlight on the chlorophyll. The sunlight probably exerts both light and heat effects on the leaf. The amount of protection afforded by the bordeaux of course is entirely dependent on the thickness of the layer on the leaf, and this varies on different leaves and on different portions of the same leaf. A moderately thin layer will reduce the light intensity by one-half while a very thick one will allow only the passage of about a fourth of the light. Schander (38) has

emphasized, perhaps too strongly, this effect of bordeaux in Germany where light intensities are relatively weak.

Leaves protected by bordeaux are slightly cooler than those which lack this covering. A thermometer held under a glass plate covered with a thin layer of the 5-5-50 mixture upon which direct sunlight pours, registers from a third to two-thirds of a degree Centigrade less temperature than when exposed to the direct sunshine. This difference, while slight, ought to be sufficient to reduce the evaporation of the leaf and to protect to some extent the chlorophyll in the palisade parenchyma from excessive destruction. Chlorophyll seems to be much more easily broken down in the potato leaf than in most plants. Incipient tip-burn usually is indicated by a yellow color of the leaf which spells chlorophyll destruction.

VIII. FLEA BEETLE INJURIES

The study of the problems of the physiology of sprayed and unsprayed potato plants in the field is complicated further in America by the holes made by the flea beetle. These injuries are much more serious on unsprayed than on sprayed plants, the number of holes being from three to four times as great. An examination of several medium sized unsprayed leaves made during the summer of 1914 showed punctures ranging in number from 30 to 112. These holes are about 0.5 to 1 millimeter in diameter. From two to six percent of the leaf structure is thus lost, whereas not more than one or two percent is eaten in the sprayed leaves. The flea beetle undoubtedly

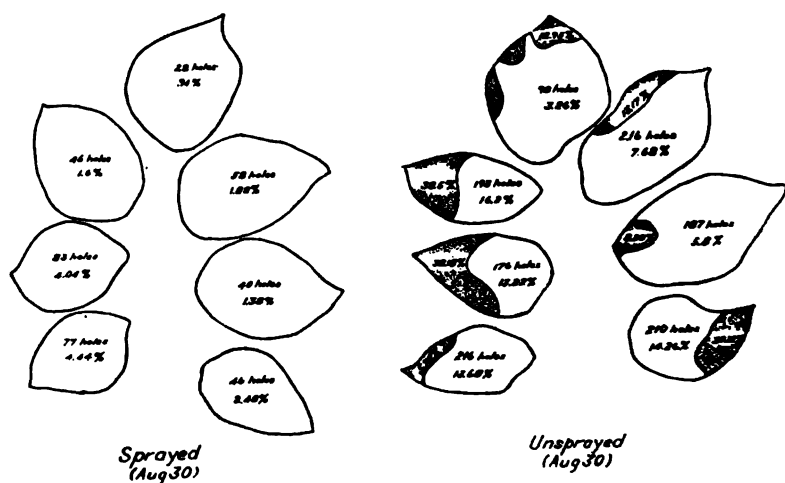


FIG. 11. Relative loss from flea beetle and tip-burn injury on sprayed and unsprayed leaves of Irish Cobbler potatoes.

on the average is responsible for about one-fifth of the loss in yield in unsprayed plants; or, reversing this statement and phrasing it in a positive manner, it is not too much to say that under normal and average seasonal conditions in this vicinity in years when true blights are absent, not far from a quarter part of the gain secured by the use of bordeaux on potatoes may be attributed to its deterrent effect as against the flea beetle; in some years more, in other years less. The flea beetle seems to be most active during those seasons when fungus diseases are not prevalent, and the plants usually are considered to be normal and healthy. Under such conditions spraying usually is worth doing, even though it only wards off the worst of the insect attacks.

In this connection the following statement as to the flea beetle injury studies is of interest. Equal numbers of thoroughly representative Irish Cobbler leaves from all parts of the plants both sprayed and unsprayed were copied in outline on August 30, 1915. The sprayed plants showed little or no tip-burn injury whereas the unsprayed ones already had suffered considerably. The flea beetle punctures for each leaflet were counted and noted and the amount of tip-burn injury was indicated as nearly as possible. Total leaf areas and also total tip-burn areas were then measured by means of a planimeter.

Area of sprayed leaves	1,074.6 sq. cm.
Area of unsprayed leaves	936.8 sq. cm.
Area of tip-burn on sprayed leaves	none
Area of tip-burn on unsprayed leaves	201.0 sq. cm.
Number of holes in sprayed leaves	2,465. sq. cm.
Number of holes in unsprayed leaves	7,901. sq. cm.
Assuming 150 flea beetle punctures to each centimeter.	
Area lost by flea beetle injury, sprayed	16.4 sq. cm.
Area lost by flea beetle injury, unsprayed	52.6 sq. cm.

Of course the flea beetle punctures could be counted only on the portions of the leaf that were still intact. Assuming that there was the same proportion of injury on the tip-burn portion, the total leaf area removed by the flea beetle would approximate 65 square centimeters.¹

The percentage then would be about as follows:—

Area of unsprayed plants lost by tip-burn	21.4 percent
Area of unsprayed plants lost by flea beetle	6.9 percent
Area of sprayed plants lost by flea beetle	1.5 percent

IX. GENERAL CONCLUSIONS

The physiological effects of bordeaux mixture on potato plants in the open field in this climate seem to be favorable. The writer ascribes

¹In this connection should be recalled the flea beetle counts on sprayed and unsprayed leaves made twenty years ago at this Station by Jones (22), who found even a smaller number of punctures on the sprayed plants than are reported here.

this result entirely to lessened tip-burn and flea beetle injuries. His earlier opinion, as expressed in bulletin 159, to the effect that spraying plants seems to tend to stimulate and to augment the daily production of starch, seems to be incorrect. The life of the starch making organs is prolonged, but these organs are not stimulated by the copper salts daily to produce more starch. The application of the copper-lime compounds is to be looked on as a protection rather than as a stimulus. Under indoor conditions there probably results from spraying a general lowering of all functions of the plant unless it be that of transpiration. Under field conditions transpiration seems to be greater from the sprayed than from the unsprayed plants, but the lowering of the other functions impairs the vigor of starch formation and removal, so that no real increase occurs from day to day. It must be admitted that the influence, helpful or harmful, of bordeaux spraying on plant life has been much overestimated, as Chuard and Porchet (8) already have pointed out on the grape. The blue-green color imparted to the foliage of sprayed plants is likely to lead the observer in the field to the conclusion that the plants are healthier than normal and that their yields will be greater. The results secured from spraying are very favorable, but the apparent cause already has been stated.

It is probable that a very even balance is maintained between favorable or unfavorable effects from spraying prior to introduction of the tip-burn. The bordeauxed plants then have the advantage. This complication is introduced so early in the problem that it is impossible to decide from early harvests, as was tried in 1911 and 1912, whether the mixture applied early in the season, had any effect on the plants. The loss in yield on the unsprayed plants as early as September 1, due to tip-burn and flea beetle injuries, is sufficient to vitiate any comparisons. The loss of foliage from tip-burn occurs earlier than the writer noted in 1911, as is shown by the fact that the unsprayed plants were somewhat lighter.

The recourse to greenhouse experimentation and to the spraying experiments in Germany was had with the intention of eliminating these factors. The numerous conflicting German tests (24) have been made where tip-burn does not occur. It is practically unknown there, although the writer has been informed by competent authority that it did occur in Germany to a slight extent during the very hot, dry summer of 1911. Tip-burn and flea beetle being eliminated, no favorable results were secured from spraying in the experiments at Bonn or in the greenhouse in 1914. The potatoes in the greenhouse in 1915 were

benefited by spraying, but for some reason tip-burn was almost as severe that summer indoors as it was outdoors.

It must be further pointed out that the results secured in spraying of beans and artichokes confirm the work at Bonn and in the greenhouse on potatoes. These two plants are not subject to tip-burn. They offer an uncomplicated opportunity to measure the stimulating effect of bordeaux, if any such exists. In no case did the use of bordeaux show the slightest result. The objection may be raised that these plants have thicker cuticles and that consequently they do not absorb the poison as readily as does the more tender leaf of the potato. This may be true, since neither the bean nor the artichoke is as succulent as the potato; or they may not be as readily affected, at least by the small quantities they cannot help absorbing. Bayer (6) noted decided changes in the appearance of sprayed bean foliage, but the writer has seen no such dark green color on either beans or artichokes.

The relative importance of tip-burn and flea beetle injury already has been discussed. The experience of two years based on estimates and actual counts of holes and of size of tip-burned areas, has led to the conclusion that the flea beetle causes from 10 to 30 percent of the total leaf losses, while tip-burn is responsible for from 70 to 90 percent. These proportions naturally vary from year to year and probably do not hold for locations other than Burlington.

Frank and Krüger's (17) contention that the increased yield secured in their experiments as a result of using bordeaux was due to the more rapid transpiration of the sprayed plants, in part is confirmed by the present work. An increase in transpiration connotes an increase in the green weight of a plant, as has been shown by Livingston (27); in fact, the transpiration of the plant is a fairly accurate measure of its size. Against this idea, that increased transpiration is an advantage, must be balanced the fact that the potato often must find it difficult to maintain the water content of its leaves. On the other hand, however, it must be recalled that the potato very rarely is found wilting in the field.

The increase in transpiration brought about by the use of bordeaux probably is a purely physical phenomenon. The use of other powders and spray mixtures doubtless would cause the same results and affect the plant in the same way, so far as water losses are concerned. The dried films or powders pressed close to the cuticle draw water from the epidermal cells and from the deeper lying palisade parenchyma. However, our 1909 spraying trials showed that lime did

not increase yields and the New York (Geneva) Station has found that lime-sulphur at times is even injurious to the plant. Potato roots in certain dry seasons and in dry, sandy soils at times must be put to it to supply the plant with the necessary moisture. It may be, too, that in a very damp climate with a minimum of sunshine bordeaux would exert the opposite effect on the plant, that is to say that it would cause a lessened transpiration. However, our greenhouse experiments would indicate otherwise. The stomata to some extent must be plugged by the bordeaux, but not to an extent sufficient to overcome the more rapid transpiration from the leaf surface induced by its use.

The most interesting problem in this entire study from the standpoint of pathology is the determination of the manner in which the copper salts prevent tip-burn. No reasonable doubt remains that these are absorbed in small quantities by the leaf. Dandeno (10) found that the copper from a dilute solution of one of its salts, allowed to dry on a primula leaf, left no stain. Chemical tests of the leaves show that the copper enters in noticeable quantities, and the diastase reaction of Ewert (16) is still more conclusive. A chemical combination is formed with some of the cell constituents, probably the chlorophyl. The difficulty with which the chlorophyl is removed from sprayed leaves indicates that it has been so changed that it is much less soluble than heretofore. Our knowledge of the synthesis and destruction of the chlorophyl is even more vague than that of the part it plays in starch formation. Anything that could be offered would be in the nature of a surmise. A comparison of this chemical substance with others that occur in the cell would lead to the conclusion that like them it is consumed as an ultimate result of its life processes. Therefore it must be continually renewed. It would seem that American sunlight is so brilliant that the chlorophyl of the potato plant is very easily destroyed. It may be that only certain portions of the molecule break down under its influence. Tip-burn usually shows first as a yellowing of a portion of the leaflet; and from this fact one would surmise that it is the constituent that gives the chlorophyl its blue or blue-green color that is lost earliest. It would appear that the copper sulphate unites with this portion and makes it more stable and more capable of maintaining its structure even in the face of brilliant, intense sunlight. The chlorophyl molecule, if it is one substance, seems to be a structure the whole edifice of which collapses if a single one of the important stones crumbles. Tip-burn, except in its last stages, is an injury due to the lack of water rather than to a pathological condition.

